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The Social Contract Between Science and Society

AGU
American Geophysical Union

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DEPARTMENTS

On the Cover
Storms and elevated water levels caused flooding in 2014 along Lake Shore Drive in Chicago, Ill. ©Joshua Mellin

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Christine W. McEntee, Executive Director/CEO

AGU American Geophysical Union

United States to Chair Arctic Council at Challenging Time

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U.S. Coast Guard cutter Healy in the Beaufort Sea.

The United States will pursue an ambitious agenda while facing many geopolitical challenges when it takes over the rotating chairmanship of the intergovernmental Arctic Council for 2 years beginning on 25 April, according to Adm. Robert Papp Jr. (retired), the U.S. Department of State's special representative for the Arctic.

The formal agenda the United States has proposed to the other parties in the council includes Arctic Ocean safety, security, and stewardship; improving economic and living conditions; and addressing the impacts of climate change, Papp said in a 12 March speech at the Brookings Institution in Washington, D. C.

"I will lay claim to our United States program probably being the most forward leaning, most ambitious program that's ever been proposed during a chairmanship of the Arctic Council," he said.

Those agenda items, which need to be approved by all eight member states, fall under the theme of "One Arctic: Shared opportunities, challenges, and responsibilities." "If nothing else comes across during our chairmanship," Papp said, "that's what I want everybody to remember."

Arctic Priorities

Papp, who served as head of the U.S. Coast Guard from 2010 to 2014, said that ensuring Arctic safety and security is of paramount importance. The Arctic "is opening up. There are new maritime routes that are developing. It's interesting, it's exciting, and I think it's going to change the world in the way we conduct commerce over time."

Adapting to climate change also is vital, he said. "We are not going to cure climate change within the Arctic Council, but we need to draw attention to the effects of climate change and also come up with ways to mitigate and adapt to it, to hopefully protect the environment of the Arctic."

He stressed the need to improve scientific monitoring in the Arctic. "We are looking at various mapping systems, sensors; we are looking at inventorying what other countries are doing and bringing them together so we can have better observations," Papp said. He also noted the great need for increased Arctic satellite coverage—whether for communications, observation, or navigation—because most U.S. satellites are not optimized for higher latitudes. "We are going to attempt to identify those [sen-

Randy Showstack

Adm. Robert Papp Jr. speaking at the Brookings Institution on 12 March.

"While we recognize the need for routine military training activity, any such activity must be consistent with international law and conducted with due regard for the rights of other nations and the safety of other aircraft and vessels."

sors] that are needed," he said, "and start moving toward getting them resourced."

Improving the economic and living conditions of people living in the Arctic is also a key agenda item, with potential projects ranging from developing renewable energy resources to improving telecommunications, he said.

Papp also focused on the need to raise the visibility of the Arctic and to convince Americans that the United States is an Arctic nation. "I've had a hard time over the years to try to convince people that we are a maritime nation, much less an Arctic nation," Papp explained.

Geopolitical Challenges

Some analysts and politicians have expressed concern about the military buildup in many areas of the Arctic by Russia. For example, Sen. Dan Sullivan (R-Ark.) stated at a 12 March hearing of the U.S. Senate Committee on Armed Services, "When you look at what the Russians are doing in the Arctic, it's actually quite impressive: impressive, but disturbing." He noted that Russia recently has made a decision to activate four new brigades in the Arctic.

At Brookings, Papp said that countries can legitimately build search and rescue facilities and upgrade airfields to provide logistics. Regarding Russian activities, he said, "I am willing to, at face value, wait and see how that develops and try to cut through some of the rhetoric that's constantly put out there."

Papp elaborated on his comments in response to major Russian military exercises that began throughout the Arctic on 16 March, a few days after the start of Norwegian military drills. He told *Eos*, "While we recognize the need for routine military training activity, any such activity must be consistent with international law and conducted with due regard for the rights of other nations and the safety of other aircraft and vessels."

Despite current tensions with Russia, particularly with regard to the Ukraine, Papp stressed in his Brookings address the importance of maintaining Russia as a key Arctic Council member. The United States and the six other council member countries not including Russia believe that "for the good of the Arctic, for the environment, and for other issues, we need to keep Russia in the fold and keep communications open," he said.

The United States "is deeply appreciative" that the other Arctic Council countries "have stood shoulder to shoulder together in terms of their opposition to the unlawful incursions in the Ukraine and Russia's violation of Ukraine's sovereignty," he said. "I have relayed the message that the military rhetoric [and] the actions by the Russians in Ukraine are not helpful to keeping the line of communication open, yet we remain committed to doing that."

Law of the Sea

Another geopolitical challenge is that the United States has not yet acceded to the United Nations Convention on the Law of the Sea. At a 5 March hearing of the Senate Energy and Natural Resources Committee, Papp testified that because the United States has not signed the treaty, the country is "at a significant disadvantage relative to the other Arctic ocean coastal states." The treaty aims to establish "a legal order" to promote the peaceful use of the oceans, conservation, and equitable use of marine resources. Papp said that becoming a party to the treaty would allow the United States to fully secure its rights to the continental shelf off the coast of Alaska.

Although a number of nations are staking claims in the Arctic, Papp told *Eos* that he is not convinced that there is a "resource rush" going on. "It's a very slow and deliberate process, and while everybody talks about it being like a gold rush, it's not like that at all," he said. He said that for years countries have been providing and developing the science to be able to validate claims under the treaty.

Meeting Resource Needs

Despite U.S. endeavors in the Arctic and plans at the Arctic Council, Papp said that others look at the lack of U.S. icebreakers and other resources in the Arctic and question the country's commitment to the region.

Papp said that the White House's 21 January executive order, "Enhancing Coordination of National Efforts in the Arctic," will help with resource needs. The executive order establishes an Arctic Executive Steering Committee to help coordinate the broad range of U.S. interagency activity in the Arctic. Papp said he hopes that the executive order will lead to setting some priorities that "hopefully lead to committing some resources as well to the needs of the Arctic."

Some, including senators at the 5 March hearing of the Senate Energy and Natural Resources Committee, have also expressed concern about a lack of resources available for Papp to conduct his work. In addition, John Farrell, executive director of the U.S. Arctic Research Commission, told *Eos*, "One of the challenges of the U.S. taking the helm of the chairmanship program is not just to propose an ambitious program but to also see that there are the resources available to implement that ambitious program to the full extent that it's dreamed to be."

Papp told *Eos* that although there are only a few people in his office, "scores" of people within the government are working on Arctic issues. "We are in a time of scarce resources and pressure on the federal government," he said. However, he said, "We are getting sufficient funding to carry out our duties right now." He explained that funding has "been pieced together within the State Department and we will do our best to make sure we are good stewards of the money that we are given."

By **Randy Showstack,** Staff Writer

Dawn Spacecraft Enters into Orbit Around Dwarf Planet Ceres

Ceres as seen from NASA's Dawn spacecraft on 1 March, a few days before the mission achieved orbit around the dwarf planet. The image was taken at a distance of about 48,300 kilometers..

Dawn came to Ceres on Friday morning, 6 March.

Early that day, NASA's Dawn spacecraft, launched in 2007, entered into orbit around the dwarf planet Ceres for a 16-month investigation of the dwarf planet. Ceres is the most massive body in the asteroid belt between the orbits of Mars and Jupiter. That study could provide scientists with a much clearer picture of Ceres as well as a better understanding of the formation of terrestrial planets, according to the agency. Dawn is the first spacecraft to orbit around a dwarf planet.

"Ceres was discovered in 1801, and it has beckoned for more than two centuries. Finally today Dawn answered that cosmic invitation," Marc Rayman, chief engineer and mission director for Dawn at NASA's Jet Propulsion Laboratory in Pasadena, Calif., said at a 6 March news briefing. "At about 4:39 a.m. Pacific time today, Ceres reached out and tenderly took Dawn into its permanent gravitational embrace." Orbit was achieved at an altitude of about 61,000 kilometers.

The Real Drama of the Mission

Rayman said that with the spacecraft's advanced ion propulsion system, which is 10 times more efficient than conventional chemical propulsion, Dawn "gradually, elegantly, gracefully crept up onto Ceres and slipped into orbit." He said the real drama of the mission "is in the opportunity to unveil the wonderful secrets of the largest unexplored world in the inner solar system."

Carol Raymond, Dawn mission deputy principal investigator at the Jet Propulsion Laboratory, said that scientists think of Ceres and Vesta—an asteroid that Dawn explored in 2011 and 2012—as building blocks of the terrestrial planets. Ceres has an average diameter of about 950 kilometers, whereas Vesta has an average diameter of about 525 kilometers.

The real drama of the mission "is in the opportunity to unveil the wonderful secrets of the largest unexplored world in the inner solar system."

Raymond said those two bodies represent about 40% of the mass of the entire main asteroid belt. Moreover, they are very different objects than most of the other material there, which she said is largely collision debris "left over from the violent scattering of material by Jupiter's gravity field."

"By the time we finish in mid 2016, we are going to know Ceres in exquisite detail, we are going to understand why it has very, very bright spots which are unique to any body in the solar system that's been explored thus far, and we are going to understand what Ceres means in terms of a building block for planets in our solar system," Raymond said.

Understanding Other Rocky Planets

Jim Green, director of NASA's Planetary Science Division, said that the exploration of Ceres will also help scientists better understand other bodies.

The area where Ceres and Vesta are located "is a region where a planet should have been, but no planet has been created. It's a region where Jupiter's gravitational interaction with this region has kept these pieces apart," he said.

"Ceres, that protoplanet, that beginning seed of a planet, now allows us to look back in time to see how terrestrial planets are put together," Green explained. "What we learn from Dawn about our building blocks, about this region, about these asteroids, I'm sure will also inform us about other solar systems and how rocky planets are created in those locations around stars," Green said.

By **Randy Showstack,** Staff Writer

Internet Users Act as Earthquake Trackers

A clock tower in Finale Emilia, Italy, that was destroyed by a 6.1-magnitude earthquake on 20 May 2012. The photo was uploaded by a user to EMSC's website following the earthquake.

Scientists around the world use an earthquake monitoring system that can relay information faster than seismometers: people with smartphones and Internet connections. When earthquakes hit anywhere in the world, visitors hit the Web, seeking information. Their site visits, tweets, and social media posts, in turn, provide seismologists with valuable information about the propagation of earthquakes.

"Twenty years ago, when I was a student, we knew an earthquake was felt because all the phones were ringing," said Rémy Bossu, a seismologist at the European-Mediterranean Seismological Centre (EMSC). "Today the people are just turning to the Internet."

EMSC is just one organization taking advantage of a plugged-in public to monitor earthquakes. The U.S. Geological Survey (USGS) also has multiple projects around the country tracking earthquakes via human means. These projects may one day help seismologists develop better strategies to alert communities that seismic energy from a recent rupture is headed their way, Bossu said.

Speed of Social Media Rivals Speed of Earthquake Signal

During his talk at the 2015 meeting of the American Association of the Advancement of Science, held in San Jose, Calif., in February, Bossu discussed a case study: the 5.8-magnitude earthquake that rocked Virginia and the surrounding areas on 23 August 2011.

Soon after the quake, about 148,000 people reported feeling shaking, using USGS's "Did You Feel It?" website. On top of that, Bossu and his colleagues reported that visitors inundated EMSC's website so quickly and consistently that a discernible uptick in hits to the website followed the propagation of the seismic waves by only a 90-second lag.

> It's not necessarily the magnitude of the earthquake or its epicenter that the public cares about. It's the level of shaking.

EMSC scientists approach citizen seismology from multiple angles, Bossu said. Those experiencing an earthquake can fill out questionnaires on EMSC's website, they can follow the center's Twitter account, or they can use the center's mobile app to quickly upload real-time thoughts and images.

It's not necessarily the magnitude of the earthquake or its epicenter that the public cares about, Bossu added. It's the level of shaking, where the earthquake is propagating, and how motion is affecting the larger population.

Within 30 seconds of a felt earthquake anywhere in Europe, EMSC scientists now detect a traffic surge on their website, with information from seismometers following about 60 seconds later, Bossu said. Scientists then track IP addresses and quickly turn incoming data into valuable information—such as a breakdown of where damage has occurred—for those who visit the EMSC website and follow the EMSC Twitter stream. For instance, if an area hit by an earthquake suddenly goes offline, this might be indicative of severe damage, Bossu said.

Citizens can also upload geotagged pictures of damage to help shorten response time from local authorities. As EMSC's technology improves and more people participate, feeds of tweets and responses to questionnaires in real time may help first responders, relatives, and other people outside affected regions get a feel for damage, neighborhood by neighborhood.

"We have created, basically, a virtuous circle," Bossu said. "We collect information that we use then to improve information to the public."

Other Citizen Seismology Projects

USGS has a similar approach, taking advantage of the world's obsession with Twitter to track the propagation and damaging effects of earthquakes.

USGS employs a system that monitors Twitter for any mention of the word "earthquake" in English and 32 other languages. These tweets are often the first indication that an earthquake has even occurred, said Paul Earle, a seismologist at USGS and the director of operations for the National Earth-

quake Information Center. Nearly 8% of the world is on Twitter, which means that even in remote areas not extensively networked with seismometers, Twitter users might provide a first alert to ground motion.

USGS's Quake-Catcher Network aims to understand earthquake propagation in the United States by having volunteers install low-cost seismometers externally on desktop computers or internally in their phones or laptops. The sensors can also be installed in schools and other buildings to monitor infrastructure.

> "You can count the Internet as a digital nervous system of our planet. You just plug it in and look at how the people react when an earthquakes strikes."

Once the internal smartphone technology is sensitive enough, Bossu said, seismologists may be able to implement early warning systems to better prepare a population for the seismic waves headed their way. These extrasensitive seismometers would pick up the signals from an incoming earthquake wave and immediately send a digital warning to the surrounding area, giving those tapped into such warning systems precious extra seconds to prepare.

A Digital Nervous System

In America, 74% of adults use social media. These numbers are steadily increasing globally, and 3 billion people are predicted to be online by the end of this year. This digital population offers seismologists a vast network of eyewitnesses with a strong desire to share their experiences online.

"You can count the Internet as a digital nervous system of our planet," Bossu said. "You just plug it in and look at how the people react when an earthquakes strikes."

By **JoAnna Wendel,** Staff Writer

Daniel Lombraña González, CC BY-SA 2.0 (http://bit.ly/ccbysa2-0)

In the Quake-Catcher program, volunteers install low-cost seismometers on their desktop computers and in public buildings to help seismologists track earthquakes.

Don L. Anderson (1933–2014)

Don L. Anderson, former president of the American Geophysical Union (AGU), passed away 2 December 2014. He was 81.

Don was a true renaissance man in the field of Earth and planetary science. In more than 350 papers published between 1958 and 2014, he sought to address problems in mineral physics, seismology, heat flow, geochemistry, tectonophysics, planetary sciences, and petrology. The emphasis of his research varied with time but remained very broad for more than 50 years.

Early Life and Work

Don was born in Frederick, Md., on 5 March 1933. After finishing high school, he accepted admission to Rensselaer Polytechnic Institute (RPI); he completed his degree with high honors in 1955. After a year with Chevron Oil, he joined the Air Force Cambridge Laboratories, where his research focused on properties of sea ice.

This assignment involved fieldwork at Thule Air Base in northwest Greenland, 1500 kilometers from the North Pole. Don's first five papers focused on the strength and other properties of sea ice, specifically on how thick ice needs to be to support aircraft that need to make emergency landings.

In 1958, he became a graduate student at the California Institute of Technology (Caltech), moving his family from Cambridge to Pasadena. The research on sea ice led Don to the more general problem of anisotropy of solids—how the speed of seismic waves varies with the direction of seismic waves traveling through a medium; isotropy is a special case when the speed is the same in all directions. His 1962 Ph.D. thesis, conducted under the supervision of Frank Press, focused on anisotropy, and the phenomenon remained a lifelong topic of interest.

His 1962 Ph.D. thesis focused on anisotropy, and the phenomenon remained a lifelong topic of interest.

Work on Seismology and Planetary Science

Don became a faculty member at Caltech in 1963 and in 1967 was appointed the director of the Seismological Laboratory, a position that he held for the next 22 years. During that time, he established the Seismolab as the world's leading institution in global seismology. His seismological research focused on Earth's structure and, in particular, its laterally heterogeneous properties. From measurements of surface wave dispersion, he inferred that the differences in shear wave speeds under continents and oceans may persist to depths as great as 400 kilometers. This was a revolutionary concept at the time; the accepted view was then that differences end at about 100 kilometers.

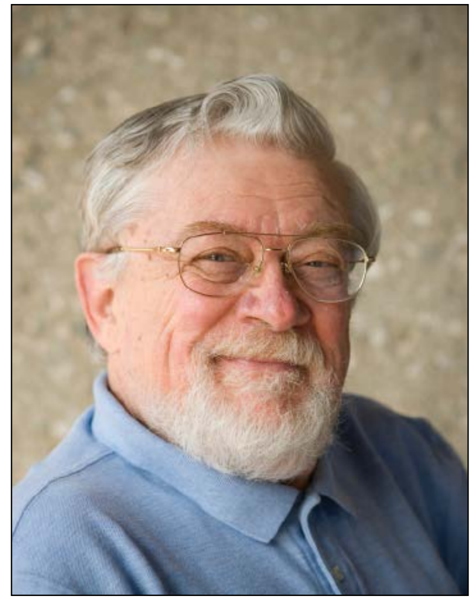
In the mid-1960s, Don also conducted intensive experimental and theoretical research on anelasticity (attenuation) of seismic waves, another important parameter that is particularly sensitive to temperature. His early accomplishments earned him AGU's Macelwane Medal in 1966—at that time, only one such distinction was granted each year.

Don became involved in planetary sciences prior to the first flights to the Moon, and he presided over the seismic component of the Viking missions to Mars. Unfortunately, contrary to his recommendation, the seismometer on Viking 1 was placed near the top of the lander and recorded only wind-generated noise; the seismometer unit on Viking 2 malfunctioned. Don called the experience of several years on the Viking planning committee one of the worst in his professional life.

Views on Plate Tectonics

The highlights of his work in the 1970s were papers on the elastic and anelastic structure of Earth. Also, Don became fascinated with the issue of the driving mechanism of plate tectonics. Although surface evidence left only a few opponents to the idea that plate tectonics reorganized continents and oceans on broad scales, the question of what makes the plates move was not satisfactorily answered.

Controversy persists regarding the spatial and temporal scale of mantle convection and how it may drive plate tectonics. For 40 years Don supported the view that the upper mantle (down to 650 kilometers depth) and the lower mantle (650 to 2900 kilometers—down to the top of the liquid core) do not mix. For much of this time, this view was opposed by geodynamicists who model mantle convection. Only recently has the view that the true answer may lie somewhere between these two alternatives become acceptable to a sizable fraction of the community.



Caltech

Don L. Anderson

Developing the Preliminary Reference Earth Model

In the early 1970s, the International Union of Geodesy and Geophysics decided that there was a need for a Reference Earth Model (REM), a description of seismic velocities and density as a function of radius from Earth's center to the surface. At a committee meeting in 1977, Don and I agreed to join forces and collaborate on the design of a specific model that would satisfy a wide variety of data: travel times of body waves, periods of free oscillations, and attenuation of seismic waves.

Several controversial issues had to be resolved. Don was a coauthor of a 1976 paper that finally led to the recognition that attenuation of seismic waves must lead to frequency dependence of the elastic moduli. Another issue was that of anisotropy; attempts to fit the data with an isotropic model led to unrealistically high velocities at the top of the mantle. Introduction of radial anisotropy, characteristic of hexagonal symmetry with the vertically oriented symmetry axis, brought these down to a realistic range,

with horizontally polarized waves having higher shear and compressional wave speeds than those vertically (or radially) polarized. The data did not demand anisotropy below 220 kilometers in depth.

The model we developed, named the Preliminary Reference Earth Model (PREM), differed from all others by including depth-dependent attenuation of shear and compressional energy, velocity dispersion, and radial anisotropy near the top of the mantle. We called it "preliminary" because we thought that it would be improved in a few years.

However, for various reasons, revisions did not happen, and the paper introducing the model now has about 7000 citations. PREM also became somewhat of a generic term; many papers use it without formally referencing it.

> The paper introducing the Preliminary Reference Earth Model now has about 7000 citations.

In the Vanguard of Seismic Tomography

Although PREM is one-dimensional (1-D), Don was fascinated with the 3-D heterogeneities within Earth, particularly in his observations of differences as large as ±10% at the top of the mantle and ±2.5% near the core-mantle boundary. Three-dimensional wave speed models, with lateral variations reflecting changes in temperature and/or composition, could provide in situ information on patterns of mantle convection.

Don embraced 3-D "seismic tomography" with enthusiasm; in my opinion, he should be credited with popularizing this term, which is now commonly used. Many of Don's papers published in the past 30 years rely on inferences from tomographic models.

A Pioneer for Broadband Seismographic Networks

The excitement caused by early 3-D tomographic models provided a fertile ground for the argument in favor of major improvement in seismic research infrastructure, on both global and regional scales. Don was an early proponent of creating a broadband, high dynamic range global seismographic network. His efforts and influence were essential in driving a community-wide initiative that within 1 year led to the formation of the Incorporated Research Institutions for Seismology (IRIS), a consortium of, at present, more than 100 U.S. universities and nearly 100 foreign associate institutions.

As a member of the first IRIS executive committee, Don was influential in securing the required support from the National Science Foundation (NSF) and the U.S. Geological Survey. Now, 30 years after its founding, IRIS is one of the most successful undertakings of the NSF's Geosciences Directorate, just one example of how Don's knowledge, vision, wisdom, and prestige benefited research in the Earth sciences. This aspect of his work was specifically acknowledged when he was awarded the National Medal of Science in 1998.

Other Honors

In 1998, Don and I were selected by the Royal Swedish Academy of Sciences to share the Crafoord Prize. The citation reads in part, "with particular emphasis on the Dynamics of the Deep Earth, for your fundamental contributions to the knowledge of the structures and processes of the deep Earth interior."

Don received many other honors. Among them are the Emil Wiechert Medal of the German Geophysical Society (1986), the Day Medal of the Geological Society of America (1987), the Gold Medal of the Royal Astronomical Society (1988), and AGU's Bowie Medal (1991). He was elected to the American Academy of Arts and Sciences (1972), the National Academy of Sciences (1982), the American Philosophical Society (1990), and many other honorific organizations and lectureships.

He contributed greatly to the activities of AGU, serving as president from 1988 to 1990. He chaired the Tectonophysics section (1972–1974) and was a member and chair of several AGU committees, mostly dealing with AGU Honors. He also served on many committees advising NASA, NSF, the U.S. Geological Survey, the National Academy of Sciences, and the National Research Council.

Persistent Dedication to Research and Scientific Debate

Don loved debating; with Gillian Foulger (Durham University, U.K.) he created more than a decade ago a website for deep and sometimes heated discussions on mantle plumes (http://www.mantleplumes.org/RoadMap.html). The site contains contributions from hundreds of scientists and has been visited by thousands.

Don worked to the very end of his life, focusing mainly on the dynamics of plate motions. His last published papers propose a paradigm of the mechanics and chemistry explaining plate tectonics. He believed that most of the activity is contained in the top 250 kilometers of the mantle (the "perisphere") and opposed the common perception of the importance and depth of the origin of hot spots. Rather than being connected to plumes traveling from the core-mantle boundary, he thought that hot spots originate near the bottom of the lithosphere. He called this paradigm "Eureka" in honor of Archimedes and the importance of flotation.

A mentor and a provocative debating partner to many, Don would often end debates with a chuckle and a twinkle in his eyes.

Don is survived by Nancy, his wife of 58 years; his son, Lee; his daughter, Lynn; and four granddaughters. He, and his great scientific mind, will be missed.

By **Adam M. Dziewonski,** Department of Earth and Planetary Sciences, Harvard University, Cambridge, Mass.

How Do High-Latitude Volcanic Eruptions Affect Climate?

High-Latitude Volcanic Eruption Impacts on Climate: Filling the Gaps
Stockholm, Sweden, 5–7 November 2014

The potential climate effects of large tropical volcanic eruptions have received much attention in the scientific climate community, but climate impacts of high-latitude volcanic eruptions have been less studied and are thus not as well understood. Increased understanding of high-latitude eruptions is also important from hazard mitigation and emergency planning perspectives. This was made evident by the 2010 eruption of Eyjafjallajökull on Iceland, which was relatively small but served as a reminder that it is only a matter of time before a similar or larger eruption will occur.

A dozen climate scientists gathered at Stockholm University in November 2014 to discuss the most recent model developments and current scientific knowledge of the effects of high-latitude volcanic eruptions on climate. The aim of the workshop was to narrow down and address the most prominent uncertainties to improve model skills in predicting the effects of future large explosive volcanic eruptions. The group focused on future research priorities to answer some key questions:

- What is the magnitude threshold for high-latitude eruptions to have large-scale or global impacts?
- How does the background ocean state affect the eruption's impact on climate?
- Does the season in which the eruption occurs matter?

What is the magnitude threshold for high-latitude eruptions to have large-scale or global impacts?

New results presented at the workshop show the potential for both short- and long-term global impacts from high-latitude eruptions, as well as the importance of ocean initial states on the associated climate anomalies, demonstrating the need for additional work on the topic.

Eyjafjallajökull's plume rising and dispersing on 16 May 2010.

The season influences sulfate formation, and the zonal asymmetry of the polar vortex can affect the aerosols' transport. Participants agreed that it would be useful to test different seasons and longitudes and to investigate the impact of Southern Hemisphere high-latitude volcanoes, where the polar vortex is zonally symmetric.

The eruption plume height is fundamental for aerosol microphysical evolutions in the atmosphere; however, little has been investigated in this regard for high-latitude eruptions. A higher spatial coverage of ice core samples would increase the signal-to-noise ratio, allowing evaluation of model skills in simulating aerosol formation, transport, and deposition. These combined efforts will provide better constraints on sulfur dioxide emission amounts and plume height estimates.

Additional key questions were as follows:

- Are we ready for the next "big one"?
- What will be the consequences for society in terms of the climate and health impacts of such an event?

It is extremely relevant from mitigation and adaptation strategy points of view to quantify the potential impacts on health of such eruptions. For example, fissures that opened up in 1783 along the flanks of Laki volcano in Iceland caused thousands of deaths across Europe and North Africa due to severe air pollution and to poisoning by volcanic gases. What would happen today? Participants contemplated this question, noting that modern societies may have increased resilience but that only a few studies have been conducted on how catastrophic eruptions could affect populations.

Sensitivity studies exploring all of the above-mentioned aspects might be model dependent. Hence, it is important to investigate climate effects of high-latitude eruptions in a multimodel framework, as proposed in the new Volcano Model Intercomparison Project (VolMIP). Modeling strategies were defined during the Stockholm workshop and could serve as an important contribution to VolMIP.

Acknowledgments
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By **Francesco S. R. Pausata,** Department of Meteorology and Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden; email: francesco.pausata@misu.su.se

Fortifying International Collaborations on African Air Quality

First West African Workshop on Air Quality, Measurements, and Modeling
Abuja, Nigeria, 9–12 June 2014


Francis Nkem Eze, CAR/NASRDA

Hands-on practical session and discussions as part of the modeling tutorial during the workshop.

West Africa has experienced rapid urbanization in recent decades. Lagos, Nigeria, is the most populated city in Africa, with more than 20 million inhabitants. Air quality there and in other West African cities is burdened by increasing anthropogenic emissions from exploitation of fossil fuels and other sources, in addition to the mix of biogenic emissions, fires, and dust that are specific to the region.

West Africa is in need of continuous, long-term measurements to quantify the current and future atmospheric composition, identify emission sources, and better comprehend the impacts on human health, ecosystems, and climate. For these reasons, the Centre for Atmospheric Research (CAR) of the Nigerian National Space Research and Development Agency (NASRDA) and the U.S. National Center for Atmospheric Research (NCAR) jointly organized a workshop on air quality, measurements, and modeling in Abuja, Nigeria, in mid-June 2014.

The workshop brought together 35 researchers, including graduate students, teachers, and scientists, from the region. The goal was to raise awareness of air pollution and associated impacts, identify existing air quality observations, discuss current and future research projects, and form new collaborations.

Ongoing research was presented on emission estimates; recent observations, including satellite and ground-based measurements; and modeling. There have been a few focused measurement campaigns, as well as limited surface observations that started in the 1990s. The upcoming Dynamics-Aerosol-Chemistry-Cloud Interactions in West Africa campaign scheduled for summer 2016 (see http://www.dacciwa.eu/) is expected to provide valuable air quality data. However, long-term surface observations currently do not exist.

Measurements and modeling were key themes of the workshop. These activities are, however, especially difficult and require devising ingenious solutions in a region fraught with challenges, such as an unstable electric grid, limited computational facilities, and background pollutants. Participants agreed that instruments must be not only affordable but rugged and capable of accurate measurements while exposed to environmental contaminants, especially dust.

NCAR provided demonstration instruments, including an ozone monitor to start the first long-term measurements in Anyigba, Nigeria. Other instruments included a commercial nitric oxide/nitrogen dioxide monitor and low-cost sensor packages for observing other important air pollutants.

Workshop participants were introduced to the regional Weather Research Forecasting Model Coupled with Chemistry (WRF-Chem) and the global Community Earth System Model (CESM). Linux virtual machines with both models preinstalled were deployed on workstations connected to uninterrupted power supply systems to overcome power outages and limited Internet access at the meeting site. WRF-Chem helped workshop participants understand the emissions and atmospheric transport of pollutants in the region, and CESM illustrated the connections between regional and global air quality, with implications for climate change.

Despite limited funding and significant infrastructure challenges, the workshop achieved its set goals and was a great success for all the participants. A workshop website has been established as a communication portal for this collaborative effort.

For more information, visit https://www2.acd.ucar.edu/west-africa/workshops.

West Africa is in need of continuous, long-term measurements to quantify the current and future atmospheric composition, identify emission sources, and better comprehend the impacts on human health, ecosystems, and climate.

Acknowledgment

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Reaffirming the Social Contract Between Science and Society

The world's 7 billion people currently struggle to solve a high-stakes, threefold problem: satisfy a growing appetite for food, energy, water, and other resources; protect the environment; and build resilience to natural extremes. In the face of this defining challenge, our geosciences community, although well-meaning and with much to offer, too often gives the impression that we care primarily about more funding for our research.

Such overt self-interest is not merely unseemly. It poses risks to our community and to society writ large. To get back on track, we would do well to take to heart some prescient 17th-century advice.

Science to Benefit Life

Four hundred years ago, the great natural philosopher Francis Bacon was concerned not just about science but also about the social contract between scientists and the rest of the world. He wrote (F. Bacon, *The Great Instauration*, 1620, as quoted by *Ravetz* [1971]),

> Lastly, I would address one general admonition to all—that they consider what are the true ends of knowledge, and that they seek it not either for pleasure of the mind, or for contention, or for superiority to others, or for profit, or fame, or power, or any of these inferior things, but for the benefit and use of life, and that they perfect and govern it in charity. For it was from lust of power that the angels fell, from lust of knowledge that man fell; but of charity there can be no excess, neither did angel or man ever come in danger by it.

As the text suggests, Bacon reached two conclusions: first, that scientists should seek knowledge and understanding to *benefit life* and, second, that *love for others* should be the primary motivation, the word "charity" being the Elizabethan term for love (as exemplified in the King James Bible translation of 1 Corinthians 13, often recited at weddings).

Bacon's thinking might strike some today as remarkable. In part that's because the natural philosophers of his day usually enjoyed independent means. By today's standards, we might imagine that self-funded scientists should not have to defend to anyone their interests or preferences for doing science. Similarly, the idea of high-minded love (seeking the welfare of others possibly at some cost to ourselves) holds little place in current discourse on science and public policy.

Today, by contrast, our (substantially more expensive) scientific research is funded largely by governments and therefore, indirectly, by taxpayer dollars. Much of the support comes from people far more strained financially than we are. This raises questions: Why should they pay us? Isn't it because they hope that our labors will improve their lot in life? Don't we owe them something? What would a fair return on society's investment look like?

And, finally, what has been our response?

How have we faced new stresses? Unfortunately, many scientists have responded by resorting to advocacy.

Modern Understanding Between Scientists and Society

With considerable oversimplification, the current social contract between scientists and society dates back to Vannevar Bush [*Bush*, 1945] and the conclusion of World War II. The United States entered the war with obsolete equipment and weapons, lagging behind the capabilities of the Axis powers in important respects. Despite this late start, the Allies ultimately claimed victory thanks in large measure to their overwhelming industrial capacity and access to natural resources and also in no small part to catch-up in technology and innovation. Examples such as radar, the atomic bomb, and penicillin come to mind. Providentially, hostilities ended before the Germans could fully capitalize on their lead in rocketry.

To address the emerging Soviet threat that would eventually lead to the Cold War, U.S. leaders demanded a broad, robust, concerted, and sustained program of research and development. They set up the National Science Foundation (NSF) in 1950; investments in atomic energy and in space technology (spurred by the Soviet launch of Sputnik in 1957) followed [*Doel*, 2003].

The language that established NSF speaks to national goals, but scientists and political leaders quickly realized that these goals would be best achieved if scientists were allowed to decide the most promising avenues of research to be pursued, based on their intrinsic merits. For a while, the language surrounding this policy even spoke of "curiosity-driven science." It's as if scientists had brashly stated to the world, "give us lots of money and don't ask too many questions, and one day you'll be glad you did."

Remarkably, both partners in this version of the social contract have kept up their side of the bargain, for perhaps a good half century. Working through Congress, the public has been both generous and constant with its funding, and scientists in turn have delivered a cornucopia of benefits in agriculture, energy, human health, information technology, transportation, and much more—including (close to the hearts of our *Eos* community) Earth observations, science, and services (Earth OSS). These advances have fueled economic growth, national security, and quality of life, as well as a place for the United States as the "indispensable nation" in world affairs.

Recent Stresses to the Social Contract

Stresses over the past decade or so have frayed the fabric of the social contract between scientists and society. The complexity and costs of science have been growing. Urgent societal challenges (in education, environmental protection, foreign relations, maintenance of aging critical infrastructure, national security, public health, and more) demand quick fixes even as they compete with the funding for science. Society has asked scientists for more help, even as research budgets have remained relatively constant. Relations have been strained on both sides.

How have we faced these new stresses? Unfortunately, many scientists have responded by resorting to advocacy. Worse, we've too often dumbed down our lobbying until it's little more than simplistic, orchestrated, self-serving pleas for increased research funding, accompanied at times by the merest smidgen of supporting argument.

At the same time, particularly in Earth OSS, as we've observed and studied emerging natural resource shortages, environmental

degradation, and vulnerability to hazards, we've allowed ourselves to turn into scolds. Worse, we've chosen sides politically, largely abandoning any pretense at nonpartisanship.

In this way, we've alienated at least half the country's political leadership—and half the country's population. In Earth sciences, our proposed social contract sounds dangerously close to this: "We're in the business of documenting human failure. But lately, the speed, complexity, and magnitude of that failure have picked up—with respect to management of natural resources, environmental stewardship, and hazard risk. If our documentation is to keep pace, we need more funding."

To a beset, struggling general public this can easily look unhelpful, even arrogant. In today's polarized and beleaguered society, that's dangerous.

Pressing the Reset Button

There is a way out. Here's a starting point, gleaned from years of engaging my wife and my daughter. The latter is a child social worker, married with sons of her own. I came to her one day with some new science: "Hey honey, I've just learned from an article that kids need to get five encouraging words from parents for every bit of criticism." She replied, "It's more like ten, Dad—and adults need encouragement, too."

Every night at home, my wife finds me doing the dishes. She sees it as helpful. But I've learned that by making myself useful, I'm really advocating on my behalf.

You've no doubt learned similar lessons at home. So how about this? As individuals and as a community, let's listen more to the people and the political leaders who support us and spend less time up front telling them what we know. Relaying our knowledge can come later; we first need to build a bridge of trust that can carry the weight of truth.

Let's show more gratitude for the support the public and public leaders have provided to date. Let's thread ourselves through the whole of society, where the pressing problems are close at hand, and collaborate in their practical solution versus studying the problems at some distance and earning the derisive ivory-tower label.

Let's do this out of a genuine, loving concern rather than as a manipulative, self-serving all-too-transparent) technique. We'll not only establish a more robust, sustainable, and productive social contract going forward; we'll set the world on a more sustainable path toward a brighter future [*Hooke*, 2014].

And Francis Bacon himself would be proud.

In Earth sciences, our proposed social contract sounds dangerously close to this: "We're in the business of documenting human failure. But lately, the speed, complexity, and magnitude of that failure have picked up… If our documentation is to keep pace, we need more funding."

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GREAT LAKES WATER LEVELS SURGE

By Andrew D. Gronewold, Anne H. Clites, Jacob Bruxer, Keith W. Kompoltowicz, Joeseph P. Smith, Timothy S. Hunter, and Cary Wong

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The recent 2-year surge represents one of the most rapid rates of water level change on the Great Lakes in recorded history and marks the end of an unprecedented period of low water levels.

Storms and elevated waters on Lake Michigan-Huron led to flooding along Lake Shore Drive in Chicago, Ill. This photo, taken on Halloween in 2014, underscores the combined effects of both a storm event and the recent rapid return of water levels to above-average conditions. October 2014 marked the first time water levels on Lake Michigan-Huron were significantly above monthly average levels since December 1998.

Water levels on Lake Superior and Lake Michigan-Huron (Lake Michigan and Lake Huron are commonly viewed as a single lake from a long-term hydrological perspective), the two largest lakes on Earth by surface area, rose at a remarkable rate over the past 2 years. The recent surge represents one of the most rapid rates of water level change on the Great Lakes in recorded history and marks the end of an unprecedented period of below-average water levels that began in 1998.

Monitoring Water Levels

Routine measurements of Great Lakes water levels have been continually recorded, documented, and communicated to the public since the mid-1800s [*Gronewold et al.,* 2013a] as part of a long-term international partnership between federal agencies including the National Oceanic and Atmospheric Administration, the U.S. Army Corps of Engineers, Environment Canada, and the Department of Fisheries and Oceans Canada.

The binational Great Lakes water level monitoring program has also served, and continues to serve, as a basis for numerous studies [see, e.g., *Buttle et al.,* 2004; *Mainville and Craymer,* 2005; *Millerd,* 2010] focused on understanding impacts of water level changes on the roughly 17,000 kilometers of Great Lakes coastline across both the United States and Canada [*Gronewold et al.,* 2013b]. These impacts include, but are not limited to, changes in waterway navigability (for both commercial and recreational vessels), hydropower generation, and tourism.

The Recent Surge

Water level data from the long-term binational monitoring program indicate that Lake Superior rose roughly 0.6 meter from January 2013 to December 2014 (Figure 1a), the highest rise ever recorded for that specific 24-month period (January through December of the next year). Similarly, from January 2013 to December 2014, water levels on Lake Michigan-Huron rose nearly 1.0 meter (Figure 1b), a rise nearly equal to the record-setting rise from January 1950 to December 1951.

Historical month-to-month water level changes (Figures 1c and 1d) indicate that the recent extreme 2-year rise on Lake Superior is associated with persistent near- or above-average water level rises for nearly every month. Notable above-average increases occurred from April 2013 to September 2013 and in April, May, and August 2014 (Figure 1c).

Similarly, the recent rise on Lake Michigan-Huron appears to be the result of not only above-average rises in the late spring and summer months (specifically April to June 2013 and April to August 2014) but also above-average rises in both September and October 2014 (Figure 1d). It is very unusual for water levels on Lake Michigan-Huron to rise in the early fall months (in only 11 of the previous 154 years on record, for example, did water levels rise from September to October).

Surge Preceded by Record Lows

Both Lake Superior and Lake Michigan-Huron had been persistently below (or, for brief periods on Lake Superior in 2004 and 2005, extremely close to) long-term monthly averages for a period of roughly 15 years following a rapid decline in the late 1990s [*Assel et al.,* 2004]. During this period, water levels reached record lows for the months of August and September on Lake Superior (in 2007) and for the month of December on Lake Michigan-Huron (in 2012).

In January 2013, Lake Michigan-Huron dropped to its lowest level on record for any month of the year [*Gronewold and Stow,* 2014]. The longest prior continuous periods of below-average water levels on Lake Superior and Lake Michigan-Huron were, respectively, 1921–1928 and 1930–1943.

Water Level Fluctuations in Context

The recent surge in water levels has provided relief to systems and economic sectors stressed by hydrologic extremes. The prolonged period of low water conditions preceding the recent surge, for example, catalyzed demands for new structures designed to reduce flow rates through the St. Clair River and increase water levels on Lake Michigan-Huron [*Gronewold and Stow,* 2014]; the recent surge has changed the context of the debate over the benefits and the urgency of putting these structures in place.

Future Conditions

Internationally coordinated seasonal water level forecasts through the summer of 2015 indicate that monthly average water levels are likely to follow their typical seasonal trends at above-average levels. Beyond that time frame, however, drivers of regional climate variability that can significantly impact regional water budgets and lake water levels remain difficult to predict [*Assel*, 1998; *Rodionov and Assel,* 2003].

The recent rise in water levels on Earth's two largest freshwater surfaces and the preceding period of below-average levels therefore underscore the need for improved understanding of how

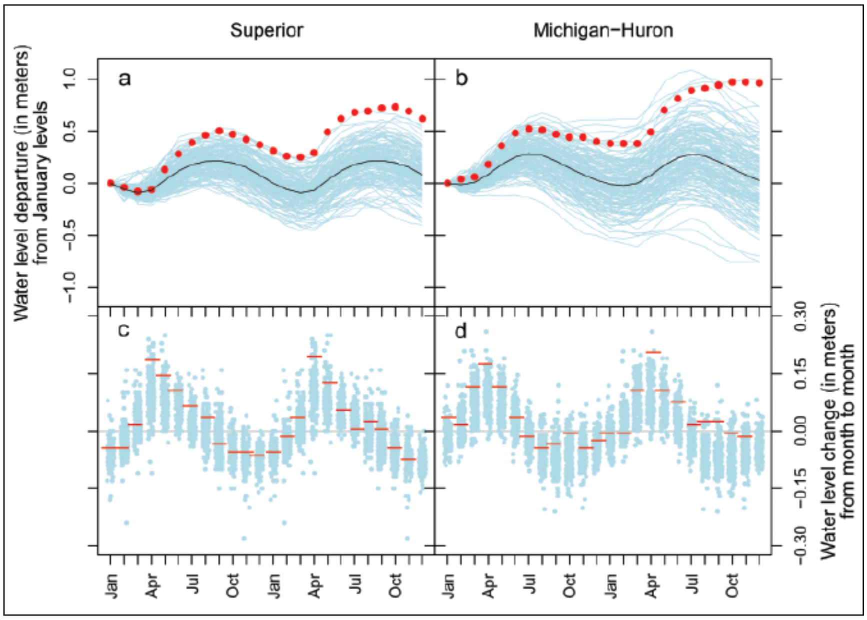

Fig. 1. Seasonal monthly average water levels on Lake Superior and Lake Michigan-Huron. (a and b) Monthly average water level anomalies relative to January levels for each historical 24-month period starting in January and ending in December of the following year (blue curves) as well as the average seasonal water level anomaly (black curve); water level anomalies from January 2013 through December 2014 are presented as red dots. (c and d) Month-to-month water level changes, with red horizontal dashes representing month-to-month changes from January 2013 through December 2014.

long- and short-term climate fluctuations (such as the 2014 Arctic polar vortex deformation [see *Clites et al.*, 2014]) propagate into abrupt changes in the regional water budget and water levels.

Future research focused on understanding interactions between large lake surfaces and atmospheric processes and how those interactions lead to changes in ice cover, surface water temperatures, and evaporation rates may provide insights that support prudent water resource management planning not just in the Great Lakes, but in other regions as well.

Acknowledgments

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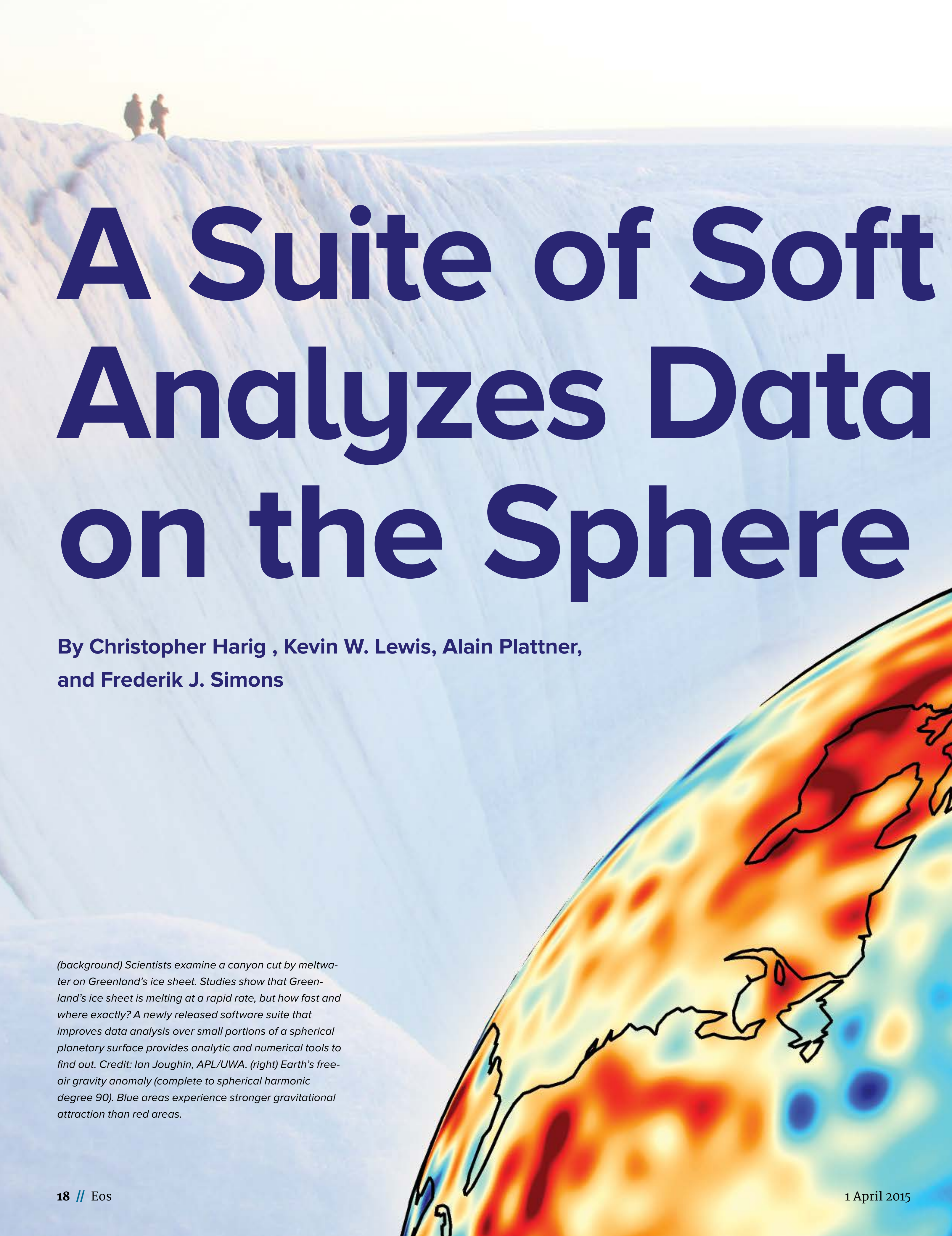
A Suite of Soft Analyzes Data on the Sphere

By Christopher Harig , Kevin W. Lewis, Alain Plattner, and Frederik J. Simons

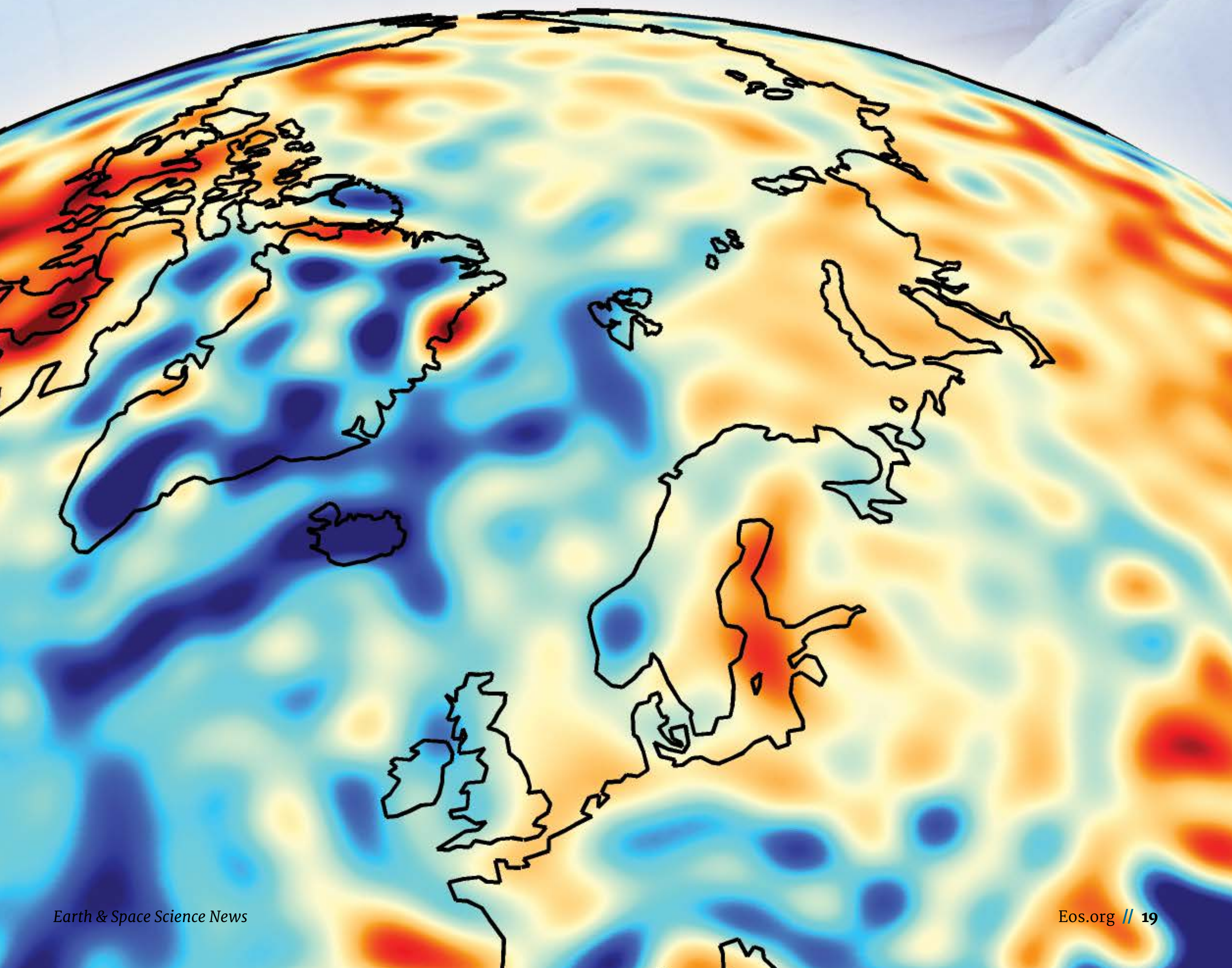


(background) Scientists examine a canyon cut by meltwater on Greenland's ice sheet. Studies show that Greenland's ice sheet is melting at a rapid rate, but how fast and where exactly? A newly released software suite that improves data analysis over small portions of a spherical planetary surface provides analytic and numerical tools to find out. Credit: Ian Joughin, APL/UWA. (right) Earth's free-air gravity anomaly (complete to spherical harmonic degree 90). Blue areas experience stronger gravitational attraction than red areas.

ware

Earth and planetary scientists frequently deal with data distributed over a spherical surface, including measurements from orbiting satellites. Often, however, the area of interest is some specific region rather than the entire sphere. Scientists might have data that only cover parts of the sphere, or they may seek to extract a local signal from a global data set.

If an area is very small, it can be approximated as a flat surface. When the region under study is not



small enough to justify two-dimensional projection, a question arises: How can one best represent the data? Here we discuss SLEPIAN 1.0, a software suite with a multitude of numerical and computational tools to accomplish spherical data analysis in the geosciences and beyond.

Estimating the geographical pattern and the temporal behavior of ice mass loss in glaciated regions serves as a prime example of a geoscientific application where getting the results right and correctly appraising the uncertainties via an open and reproducible process are of great importance. We wrote the new software partly to examine variations in regional gravity in Greenland over time. The gravity fields, obtained monthly, vary because of localized changes in the ice mass. A decade of analysis has revealed pronounced cumulative ice mass loss.

Data Analysis in the Real World

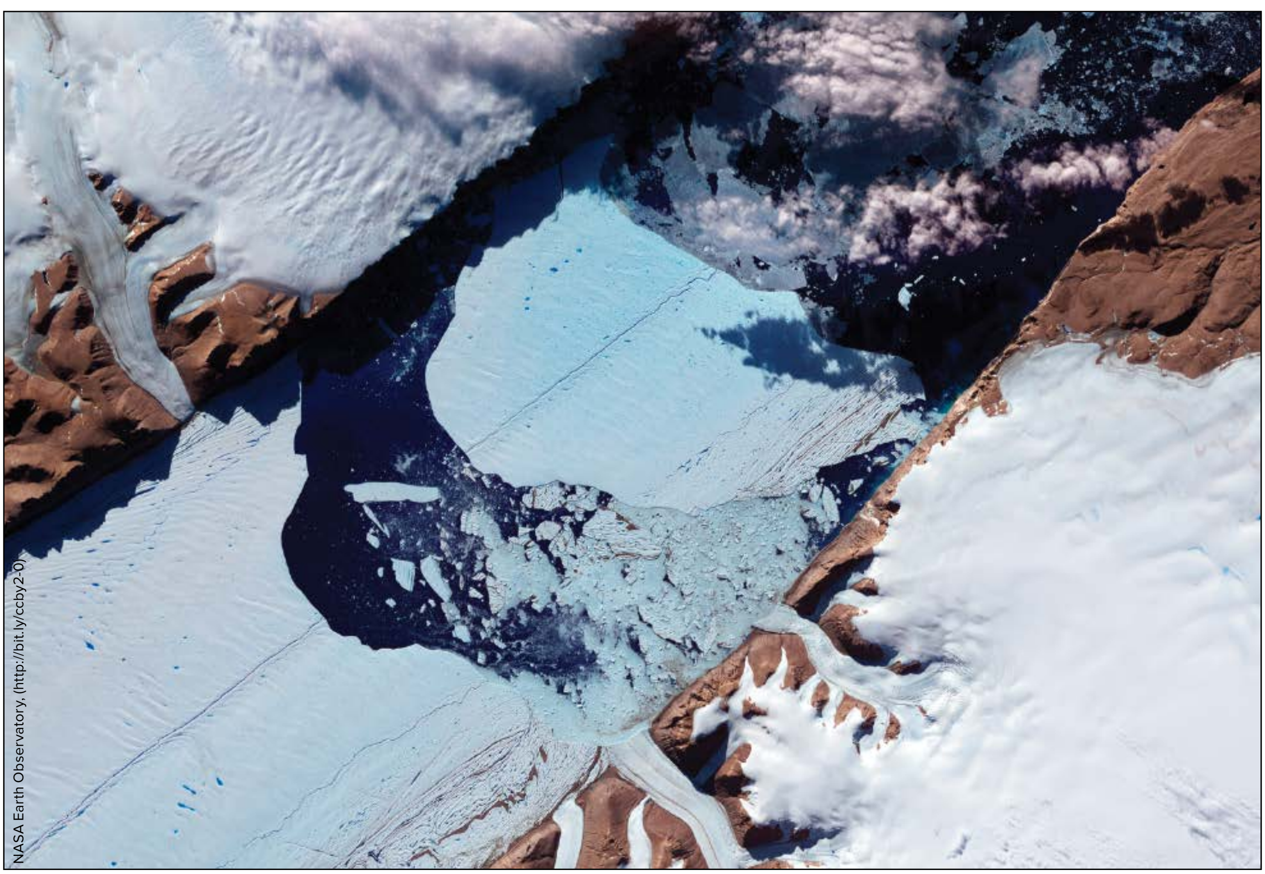
We consider "data" to be "signal" contaminated by "noise," and our objective is to recover the signal from the data via "inversion." Ideally, satellites collect data—say, on variations in the magnetic and gravitational fields of Earth or other planets—on orbits that uniformly cover the entire sphere. This makes it possible to describe the underlying magnetic and gravitational potentials mathematically in terms of spherical harmonics, which are functions defined globally over the sphere that contain information from specific spatial frequencies of the signals under consideration.

However, in practical applications, there may be gaps in the data, or the regions of interest may cover only a small part of the sphere. Analyzing incomplete (and noisy) data sets using global functions over local regions increases the effect of noise on the results.

Additional complications arise because data from real-world measurement devices do not capture all the spatial frequencies in the signal. What scientists and engineers call "limited bandwidth," in this case, would cause a geophysical signal with a lot of spatial (high-frequency) detail to be recorded poorly, making it appear much smoother (low frequency), for instance.

For analogy, representing a time-limited (one-dimensional) signal using a band-limited set of infinitely long functions (such as a subset of sines and cosines, oscillating with different frequencies) is inefficient and prone to errors and artifacts [*Slepian,* 1983]. Addressing similar data analysis challenges that arise in two dimensions, on the surface of a sphere, motivated our development of theory and software tools for analyzing and representing geoscience data.

Therefore, caution is appropriate: Using spherical harmonics to analyze noisy data on small patches of restricted data availability is often not appropriate.



A huge chunk of ice broke off from Greenland's Petermann Glacier on 21 July 2012, seen here in a false color image taken by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on NASA's Terra satellite. What broader dynamics in ice loss may have helped to lead to this event? New software may provide clues.

To improve the precision and accuracy of geoscientific modeling, we developed “Slepian functions” as an alternative to traditional spherical harmonics.

A nonglobal modeling domain and a limited observational bandwidth lead to complications and inaccuracies in the information that can be recovered from the available data. Such inaccuracies could misinform policy makers looking to use science as a basis for actions to mitigate, say, effects of climate change.

To improve the precision and accuracy of geoscientific modeling, we developed “Slepian functions” as an alternative to traditional spherical harmonics. Slepian functions are the band-limited functions best suited to analyze data over spatially limited regions of a sphere, and they form the foundation for our software suite (Figure 1a).

SLEPIAN 1.0

The SLEPIAN software suite has been available piecemeal for more than a decade, and portions of it have found application in many disciplines [e.g., *Kelbert et al.*, 2008; *Milbury and Schubert*, 2010; *Lessig et al.*, 2012; *Kim and von Frese*, 2013]. The computer codes have been used to analyze data from planets, moons, and Earth, solving problems in geophysics, astrophysics, and cosmology.

Over the past decade, our efforts have gained enough maturity and adoption by the community to warrant an official release. SLEPIAN 1.0 is a collection of algorithms in a publicly hosted code archive. At its core are a number of MATLAB functions that construct, via optimization, scalar spherical Slepian functions on arbitrarily shaped domains [*Simons et al.*, 2006]. We call this core set of algorithms SLEPIAN_Alpha.

A second group of algorithms (SLEPIAN_Bravo) solves the linear inversion problem of extracting a signal from partially and noisily observed data on the surface of a sphere—in terms of those Slepian functions [*Wieczorek and Simons*, 2005; *Simons and Dahlen*, 2006].

A third group of algorithms (SLEPIAN_Charlie) performs quadratic estimation of the power spectral density to estimate from the data the amount of energy per area that the signal has as a function of spatial frequency. Here multiple Slepian functions selectively isolate geographic regions of interest [*Wieczorek and Simons*, 2007; *Dahlen and Simons*, 2008]. The codes compute the bias and variance of the results; in other words, they provide statistical measures for their quality, enabling comparisons with other methods.

The fourth set of routines (SLEPIAN_Delta) is specifically for the analysis of time-variable gravitational potential data products from Gravity Recovery and Climate Experiment satellites (GRACE) [*Tapley et al.*, 2004], for example, to

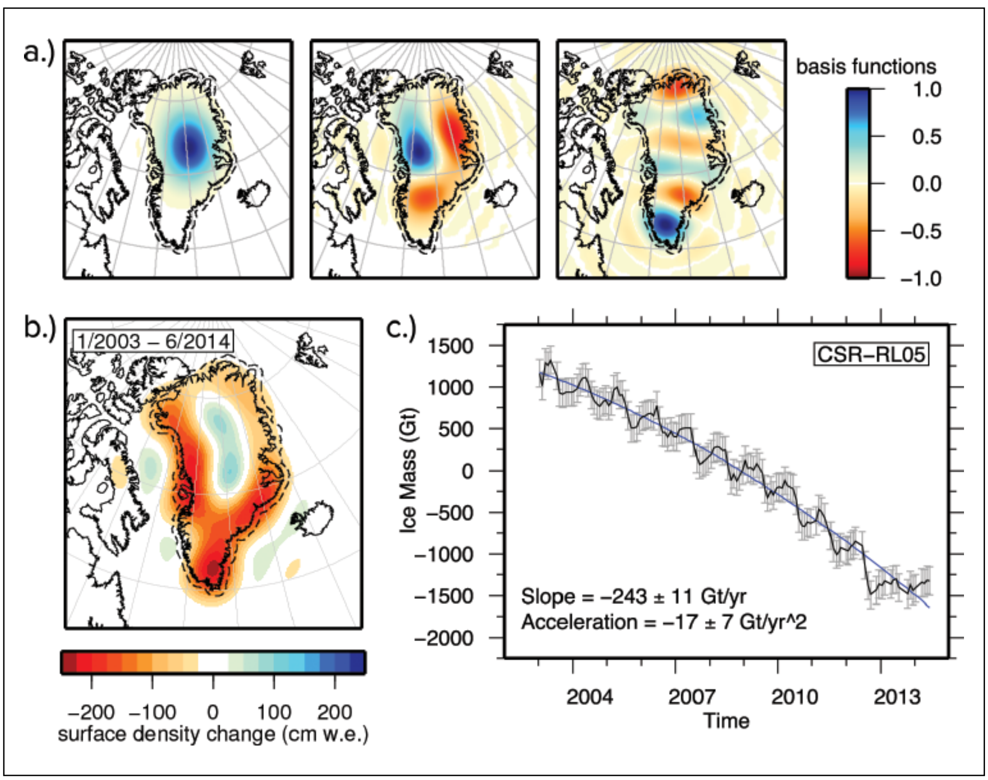


Fig. 1. (a) Three Slepian functions for the dashed region around Greenland, complete to spherical harmonic degree and order 60. Each of the mathematical functions (shown from left to right are the first, fifth, and ninth functions from the complete set) is a “template” map pattern for the ice mass loss that we recover from the data. The full set of 20 such functions, with the proper weightings derived from the data, yields the modeled ice mass loss pattern shown in Figure 1b. (b) Greenland's total ice mass change from Gravity Recovery and Climate Experiment (GRACE) data collected between January 2003 and June 2014, in centimeters of water equivalent per meter squared. The total mass loss integrated over the region for this time period is 2412 gigatons. The image has been corrected from the version printed in the 1 April magazine. *(c) Greenland's ice mass loss, shown in monthly continent-wide averages over the past decade, in gigatons. Error bars show plus and minus twice the standard deviation and the best fit quadratic function that describes the accelerating behavior.*

map ice mass loss in glaciated regions [see *Harig and Simons,* 2012, 2015].

SLEPIAN 1.0 has a modular structure that separates the algorithmic data analysis from the input-output control (which will be specific to the application) and the plotting scripts (for which the Generic Mapping Tools remain a powerful alternative [*Wessel and Smith,* 1998]). The modularity should enable the expert open-source developer to recreate key pieces of the analysis in Octave or Python while enabling end users to conduct their data analysis from start to finish in the same MATLAB environment, be it a basic configuration suited for students or a professional-grade installation on a cluster of computers. Key components of SLEPIAN 1.0 can take advantage of MATLAB's parallel computing capability. This makes it competitive in speed with the Fortran95 package SHTOOLS [*Wieczorek,* 2014], to which SLEPIAN 1.0 is closely related.

Application to GRACE Data Analysis

We used SLEPIAN 1.0 to analyze variations in Greenland's gravity field over time, using data from GRACE. The goal of this analysis was to map the geographical details of Greenland's ice mass loss over time.

GRACE mission data are released in terms of the "usual" spherical harmonics, which provide a mathematical description of the whole-Earth gravitational potential over time. To isolate the local details of the gravitational field due to the changing mass of ice near the surface, we removed the gravitational contributions from Earth's mantle, which is still adjusting from the last time polar ice caps melted since coming out of the last ice age.

We transformed the monthly data sets into our Slepian function set, separating local signal from global noise and selectively limiting the analysis to Greenland to avoid picking up spurious contributions unrelated to ice melting from surrounding areas. From the time series of these coefficients, we estimated the spatial patterns of ice mass change (Figure 1b) and the cumulative ice mass loss (Figure 1c).

Localization induces welcome sparsity: Each full-resolution gravity field solution for Greenland is represented by just 20 Slepian functions. In contrast, spherical harmonic expansions would require solving for 3721 terms.

Projection of the GRACE solutions into our truncated Slepian function set lessens the need for the smoothing, filtering, and insufficiently selective noise removal commonly applied otherwise.

Finally, uncertainty quantification is central to the Slepian estimation procedure. The mathematical properties of the functions allow scientists to account for contributions from the individual coefficients to the uncertainty in the estimates of ice mass loss trends and in maps.

Solving Problems in the Geosciences and Beyond: A Community Effort

We encourage the community to contribute to the development of the SLEPIAN suite. The code is hosted under version control by the Community Surface Dynamics Modeling System group at the University of Colorado, Boulder (see http://csdms.colorado.edu). As SLEPIAN 1.0 will continue to evolve, its user base will grow, and we foresee that it will be used for an ever-expanding range of applications.

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Seismic Stress Modeling Puts Istanbul in the Crosshairs

"Pancake collapse" of an apartment building following the M_w *= 7.6 Izmit earthquake, which shook western Turkey in 1999.*

Over the past century, a string of devastating earthquakes rocked Turkey, killing more than 80,000 people. Two of the largest events, the 1939 Erzincan earthquake and the 1999 İzmit and Düzce earthquake pair, killed 32,700 and 18,000 people, respectively. According to new research by *Ergintav et al.*, the most significant seismic hazard—potentially up to a magnitude 7.2 event—is most likely posed by a section of fault centered just a few dozen kilometers south of Istanbul, home to more than 14 million people.

The Erzincan, İzmit, and Düzce earthquakes were just three in a string of more than a dozen major ruptures of the North Anatolian Fault, a major seismic system that runs east–west across northern Turkey. As previous research has shown, over the past century, the epicenters of major earthquakes on the North Anatolian Fault have been steadily creeping westward.

Using 20 years of GPS ground motion observations, the authors modeled the accumulation of seismic strain in the North Anatolian fault system. Their calculations give an indication of where the next big earthquake is likely to hit. The authors suggest that a stretch of the fault system near the Prince Islands, an archipelago in the Sea of Marmara just south of Istanbul, is the most likely candidate. They found that the region is seismically locked—it should be slipping about 10 to 15 millimeters each year, but it is not.

Previously, researchers suggested that a stretch of the fault system much farther west, out in the Sea of Marmara, was the most likely candidate for an impending earthquake. The authors' observations suggest that this region is not accumulating stress. The authors' research, then, moves the most likely location for a major earthquake closer to Istanbul.

The last time the fault section near the Prince Islands ruptured, in 1766, it caused massive damage to Istanbul. (*Geophysical Research Letters*, doi:10.1002/2014GL060985, 2014) **—Colin Schultz, Freelance Writer**

Survey Shows Where Arctic Marine Bird Populations Thrive

The Arctic marine ecosystem depends on sea ice—algae growing under sea ice are consumed by crustaceans and fish, which are in turn consumed by seabirds. However, the ecosystem is changing in response to rapid sea ice melting. Decreasing amounts of sea ice will also increase development and tourism in the Arctic. These threats to ecosystem health make conservation a priority.

To create a baseline for use in future climate change studies that will guide conservation efforts, *Wong et al.* observed seabird distribution on and over marine areas in the North American Arctic from 2007 to 2012 during July and August.

The North American Arctic is home to millions of seabirds, including murres, auklets, petrels, puffins, seagulls, and sandpipers. Seabird populations can be indicators of ecosystem health because of their wide variety of foraging modes. The three foraging modes of Arctic seabirds include surface feeding, plunging, and diving. Surface feeders catch prey from the surface of the water, plungers catch prey by dipping into the water from flight, and divers catch prey by diving into the water from the surface.

Susan van Gelder, CC BY-NC-SA 2.0 (http://bit.ly/ccbyncsa2-0)

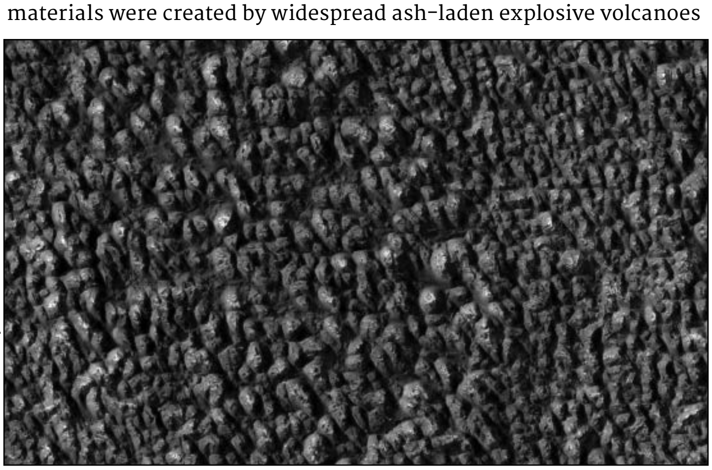
A thick-billed murre, perched on sea ice.

For the purpose of the study, the team divided the North American Arctic into west and east sections using the meridian passing through Kugluktuk, Nunavut, as the dividing line. Two vessels conducted seabird surveys in July and August 2007–2012. The western vessel transited between Victoria, British Columbia, and Kugluktuk, and the eastern vessel transited between St. John's, Newfoundland and Labrador, and Kugluktuk. The team recorded the number and species of seabirds observed on the sea surface within a 300-meter-wide transect. Instantaneous counts (e.g., rapid visual surveys of all the creatures counted in, say, 1 minute) were used for birds flying within 300 meters of the research vessel.

The researchers found more species of all foraging guilds in the western Arctic than in the eastern Arctic. "Hot spots" of species richness include the Bering Sea, Lancaster Sound, Baffin Bay, and Davis Strait. Only a few seabirds were observed between Dolphin and Union Strait and King William Island. Future surveys will show how populations change as more sea ice disappears. (*Journal of Geophysical Research: Oceans,* doi:10.1002/2013JC009198, 2014) **—Catherine Minnehan, Freelance Writer**

"Knobby Terrain" a Sign of Mars's Explosive Past

The red planet's upper crust is brittle and weak. Planetary geologists often attribute this to effusive eruption—lava pouring out of volcanoes onto the ground—early in Mars's history that later weathered down. However, some have suggested that the friable materials were created by widespread ash-laden explosive volcanoes that were eroded by geologic processes over the course of Martian history.



NASA/JPL/University of Arizona

An image of Mars's "knobby terrain" captured by the High Resolution Imaging Science Experiment, a camera aboard the Mars Reconnaissance Orbiter.

Scientists have had a tough time sorting out these different origin theories because ancient volcanoes were ultimately buried by lava from more recent eruptions. However, several volcanic regions identified in recent years are home to some of the red planet's oldest volcanoes. These ancient regions, Circum-Hellas and Arabia Terra, also hint at a history of explosive eruptions.

Huang and Xiao have identified 75 additional ancient volcanoes across Mars's surface. Using high-resolution satellite images and heat-sensing instruments, the researchers found a unique knobby terrain in 17 of those volcanoes. The pair also noticed similarities to eroded features on Earth called ignimbrites, which form as a result of huge explosions of pyroclastic ash and rock flowing down volcanic slopes. The comparison is supported by spacecraft data showing that the features are made of a fine-grain material. Spectral data also indicate that the knobby features were eroded by liquid at some point in the past.

The scientists interpret their observations as a sign that these knobby features formed in pyroclastic explosions early on Mars and were later eroded. If the finding is correct, it would lend support to the theory that explosive volcanism was dominant on Mars in the distant past. (*Geophysical Research Letters*, doi:10.1002/2014GL061779, 2014) **—Eric Betz, Freelance Writer**

Cosmic Dust Helps Form Clouds, Fertilize Plankton

European Southern Observatory/Y. Beletsky

Sunlight reflects off cosmic dust particles between the Sun and Earth, creating the visual phenomenon known as "zodiacal light."

Every day, thousands of pounds of meteor debris enter Earth's atmosphere and eventually settle on the surface. Only a small fraction of these particles are large enough to be seen as shooting stars; most burn up high in the atmosphere, leaving behind a haze of tiny particles—meteoric smoke—suspended about 70–100 kilometers above Earth's surface. The dust is mostly 4.6-billion-year-old leftovers from the messy accretion process of solar system formation, which the planet picks up as it passes through long-decayed comet tails and remnants of asteroid belt smash ups.

Estimates vary greatly as to how much cosmic dust lands on Earth, ranging from 0.4 to 110 tons a day. Those larger numbers stem from measurements made on spacecraft solar panels and accumulation rates of cosmic elements found in polar ice cores, which are largely in agreement with each other. Measurements based on radar observations of meteoric smoke, however, indicate that the amount of cosmic dust making it to the surface is on the lower side of that range.

To narrow that range, *Gardner et al.* collected Doppler lidar measurements of sodium and iron particles made at the Starfire Optical Range in New Mexico and combined them with model predictions of how these particles—thought to be the remnants of cosmic dust—are transported. From this information the authors estimated the rate of cosmic dust entering Earth's atmosphere every day. Their estimate landed right in the middle of the existing range, indicating that roughly 60 tons of cosmic dust infiltrate the atmosphere.

These meteoric smoke particles are not just depositing significant amounts energy and mass into the atmosphere, however. They are also influencing processes that scientists are only just beginning to understand. Studies have shown that the cosmic dust can contribute to cloud formation in the upper atmosphere and can fertilize the growth of plankton in Antarctica. The team says that determining the exact amount of cosmic dust hitting the atmosphere will help them understand the role these particles play in an increasing number of other phenomena. (*Journal of Geophysical Research: Space Physics*, doi:10.1002/2014JA020383, 2014) **—Eric Betz, Freelance Writer**

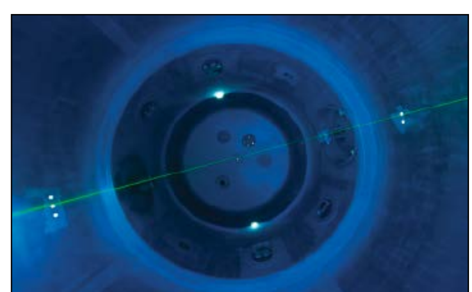
Precooled Aerosols Are Better Raindrop Nuclei

At midlatitudes and high latitudes, droplets of water vapor condense and coalesce around a particle, such as bacteria, dust, salt, or other atmospheric aerosols. If these frozen droplets grow large and heavy enough, they fall to the surface as precipitation. If not, they can remain aloft as clouds.

Under most circumstances, these atmospheric aerosols can only become viable cloud condensation nuclei above a certain altitude. For water vapor to freeze to a nucleus and start the raindrop formation process, the temperature needs to be below a specific temperature—around 264 kelvins.

In some cases, nuclei can initiate raindrop formation even at temperatures above this marker if they have been "preactivated." Nuclei are preactived if they have previously acted as a condensation nuclei or if they have recently been cooled to below 235 kelvins. This preactivation, researchers think, makes the nucleus more amenable to water vapor condensation.

Through a series of cloud chamber experiments, *Wagner et al.* outline a third potential preactivation mechanism. This mechanism applies to organic and inorganic aqueous solutions, a range of atmospheric constituents that have only recently come under investigation for their role as cloud condensation nuclei.



Martin Lober, Karlsruhe Institute of Technology

A cloud chamber with a laser beam used to detect frozen droplets.

The authors found that when aqueous solutions of ammonium sulfate, oxalic acid, and succinic acid are cooled below 235 kelvins, they form crystalline aerosols interspersed with pockets of water ice. Introducing these preactivated aerosols to a warmer environment triggers cloud nucleation, with water condensing to the warming ice pockets. This precooling allows aerosols to act as nuclei even at temperatures above that at which it would normally be possible.

Although one of the previously known preactivation mechanisms also involves precooling, that mechanism revolves around deposits of ice on the nucleus's surfaces, whereas this one deals with ice inclusions. (*Journal of Geophysical Research: Atmospheres*, doi:10.1002/2014JD021741, 2014) **—Colin Schultz, Freelance Writer**

Fluctuations in Atlantic Meridional Overturning Circulation

The Atlantic Meridional Overturning Circulation (AMOC) is a large-scale convection cell in the Atlantic Ocean that transports warm surface water from the tropics northward and colder deeper water from the North Atlantic southward. Now a study suggests that observed interannual fluctuations in the AMOC may be forced by changes in wind patterns. Understanding the mechanisms contributing to the AMOC fluctuations is important for future climate studies.

Sherrie Thai, CC BY 2.0 (http://bit.ly/ccby2-0)

Wind may drive drive fluctuations in large scale ocean circulation.

Nearly 90% of the heat transported by the ocean at 26°N latitude is carried by AMOC. However, AMOC can fluctuate—it increased in flow from 2004 to 2005 and subsequently decreased, reaching a minimum in the 2009–2010 winter. Heat transport fluctuations impact weather patterns on both regional and larger scales. Earlier studies showed that AMOC variations are directly linked to the summer climates of North America and western Europe.

Zhao and Johns sought to explain the physical mechanisms for the observed AMOC variability. Typically, scientists rely on theoretical analysis and numerical models to explain AMOC variations because of a lack of observational data. The authors combined daily measurements of AMOC at 26.5°N from 2004 to 2011 and numerical models to explain the observed variability.

Three separate components make up the upper branch of the AMOC at 26.5°N latitude: the Gulf Stream, Ekman transport, and upper mid-ocean (UMO) transport. The team compared the fluctuations of AMOC with the fluctuations of each component. The numerical models show that AMOC variations are driven by wind. Although the Gulf Stream and Ekman transport play important roles, UMO was found to be the dominant component in AMOC fluctuations. (*Journal of Geophysical Research: Oceans*, doi:10.1002/2013JC009407, 2014) **—Catherine Minnehan, Freelance Writer**

Shape of Stream Channels Gives Clues to Sediment Size

Data from 541 alluvial rivers—those with banks made up of sediment—from a variety of regions and environments form the basis of a new study by *Trampush et al.* The study seeks to tease out how water flows in modern stream channels.

In alluvial rivers, water interacts with soil or sand, sometimes with enough force to carve into the bank. However, there is no universal understanding of how the shapes of the channels relate to the forces on the sediment—a relationship useful for understanding the behavior of water in a channel based on just a snapshot in time.

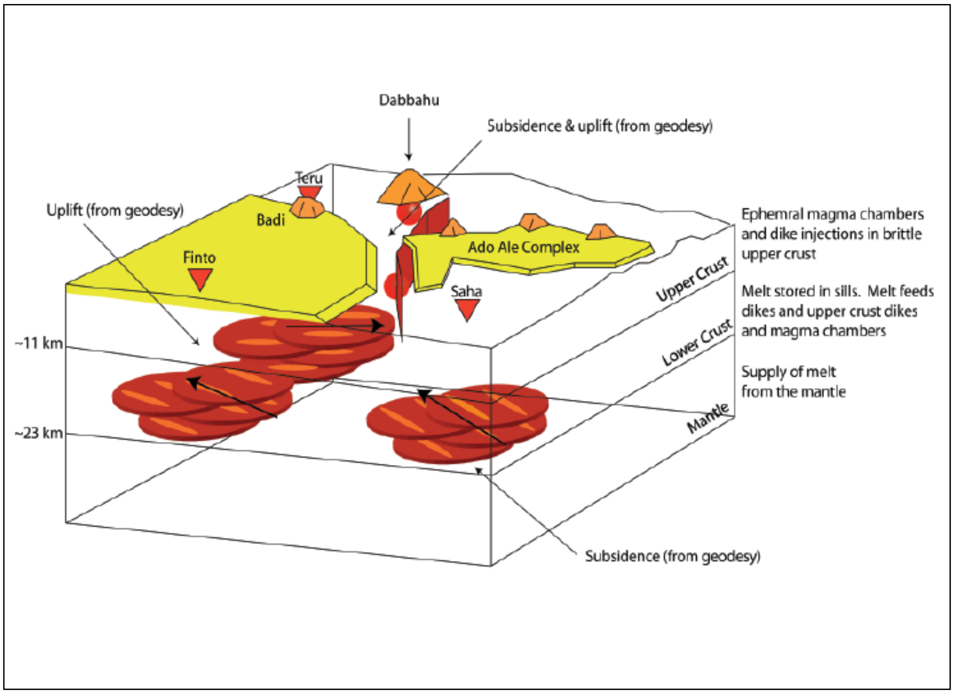
Toward a universal understanding, the authors expanded on previous works that found empirical relationships between the size of the particle and the force, known as the "Shields stress," that is required to carve a particle away from the bank in modern rivers. The authors started by doubling the number of rivers that had been used in the previous study. Then, for each river, they looked at more than 10 years of data on the depth of the banks, their slopes, and the grain sizes that make them up. Analyzing the data, they found that the relationship between particle size and Shields stress is related to the physical features of the channel.

This means that a broad view of the shape of alluvial channels can give scientists clues to grain size and the force required to carve sediment from its bank. In addition to quantifying flow characteristics of modern alluvial rivers, the relationship can quantify how water flowed in ancient channels, the authors say. For now, however, the relationship is restricted to channels on Earth. (*Water Resources Research*, doi:10.1002/2014WR015597, 2014) **—Shannon Palus, Freelance Writer**

Brandon McElroy

The layers exposed after a river slices through a sandbar show how banks along alluvial channels change their shape through continuous erosion and deposition.

A Modified Technique to Remotely Detect Subsurface Melt



J. O. S. Hammond

Conceptual model for the magmatic plumbing system around the Dabbahu–Manda Hararo rift segment. Melt in the lower crust is likely stored in stacked sills with some vertically oriented melt connecting these sills.

Depending on rock composition, temperature, pressure, and other factors, seismic waves propagate through the crust at different speeds. These factors affect primary and secondary seismic waves to a different degree. Building on this distinction, researchers have developed a technique known as H-κ stacking that uses energy bouncing in the crust to estimate the ratio of primary to secondary wave speeds and measurements of crust thickness to estimate crust properties.

However, H-κ stacking ignores an important known factor affecting seismic wave propagation. In new research, *Hammond* shows that this omission seriously affects the utility of H-κ stacking.

As previous research has shown, most crustal materials that seismic waves pass through are anisotropic. That is, a wave's speed is affected by the direction and angle of passage through the crust. In previous iterations, researchers using H-κ stacking have ignored this effect, instead treating seismic waves isotropically. However, because primary and secondary waves are affected differently, the modulating effect of anisotropy has the potential to strongly skew the primary to secondary wave speed ratio.

In his paper, the author outlines a new version of H-κ stacking designed to account for anisotropy. More than just clearing up a potential source of error, an H-κ stacking approach that accounts for anisotropy opens up the technique to new uses.

One important source of anisotropy in the crust is the presence of melt inclusions—pockets of melted or partially melted material. How melt is stored and moves throughout the crust is a key factor in determining how volcanoes erupt.

Applying his technique to observations from the Afar Depression in Ethiopia, the author found that his modified H-κ stacking approach could be used to estimate the presence and properties of melt inclusions within the crust. (*Geochemistry, Geophysics, Geosystems*, doi:10.1002/2013GC005186, 2014)

—Colin Schultz, Freelance Writer

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Atmospheric Sciences

Postdoctoral Scientist in Radiative Forcing Model Intercomparison Project

The Atmospheric and Oceanic Sciences Program at Princeton University, in association with NOAA's Geophysical Fluid Dynamics Laboratory (GFDL), seeks a postdoctoral scientist for research related to atmospheric radiative transfer modeling. The scientist will perform research into the transfer of solar and longwave radiation in the Earth's atmosphere with the aim of quantifying the roles of greenhouse gases, aerosols, and clouds.

A Ph. D. in Atmospheric Sciences or a related field is required, with specialization and demonstrated ability to carry out independent research in atmospheric radiative transfer. Skills in radiative transfer computations will be needed to use state-of-the-art benchmark models and climate model parameterizations. Programming skill in Fortran is essential. Knowledge of the role of aerosol radiative processes in climate and climate change, and skills in evaluating radiative transfer calculations with appropriate observations, are desirable.

Initial appointment is for one year with the possibility of renewal subject to satisfactory performance and continued funding. Complete applications, including a CV, publication list, contact information for three references, and a one-to-two page statement of research interests should be submitted by June 1, 2015 to ensure full consideration. For further information, contact David Paynter (David.Paynter@noaa.gov). Applications should apply online to http://jobs.princeton.edu, Requisition 1500204. These positions are subject to the University's background check policy. Princeton University is an equal opportunity employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability status, protected veteran status, or any other characteristic protected by law.

Program Director - National Suborbital Education and Research Center University of North Dakota

The University of North Dakota seeks a Program Director to manage the National Suborbital Education and Research Center (NSERC). NSERC provides science mission operations support to meet the research, education, and technology needs of the NASA Airborne Science Program and the scientific community. The Program Director will be responsible for science operations support for various aircraft platforms, including the DC-8, P-3B, C-130, Global Hawks, and ER-2s, as well as for interfacing to the scientific community. Duties include mission planning, personnel scheduling, budgeting, logistical support, and supervision of NSERC staff. In addition, the Program Director will be expected to lead the implementation of improvements that will make the various airborne platforms more scientifically valuable. The Program Director will also be responsible for the organization and improvement of training and communications for the Airborne Science Program including the annual NASA Student Airborne Research Program (SARP).

Qualifications include a graduate degree in a natural or physical science, or in engineering. Extensive experience directing research from multiple aircraft platforms is also required. Significant management experience is required including financial and personnel management. The Program Director will be expected to have strong interpersonal and leadership skills, as well as an ability to communicate effectively with a broad spectrum of clientele including NASA Headquarters management. He or she should also demonstrate an ability to collaborate with scientists and aircraft operations personnel. Experience directing student research is highly desirable. A history of success earning external funding will be a plus.

Applicants are required to be eligible for employment under U.S. export control laws and must meet the requirement of being a "U.S. Person" (U.S. citizen, a lawful permanent resident, refugee, or granted asylum) or must be eligible to obtain appropriate U.S. Government authorization for access to export controlled equipment, technology, or software. UND will not sponsor an applicant for employment authorization for this position. All information collected in this regard will only be used to ensure compliance with U.S. export control laws, and will be used in compliance with all laws prohibiting discrimination on the basis of national origin and other factors.

NSERC is affiliated with the Earth System Science and Policy Department within the John D. Odegard School of Aerospace Sciences at the University of North Dakota. More information is at http://www.nserc.und.edu/. NSERC is funded through a long-term cooperative agreement with NASA. This opening is a twelve-month, non-tenure-track faculty position with the possibility of renewal.

Interested candidates should submit a CV, list of publications, statement of research and education interests, and contact information for three references to: Karen Katrinak, NSERC, UND Earth System Science & Policy Dept., Clifford Hall Rm 300, 4149 University Avenue Stop 9011, Grand Forks, ND 58202-9011; phone (701) 777-2482; fax (701) 777-2940. Applications may be e-mailed to: k.katrinak@nserc.und.edu. Applications received by April 6, 2015 will be considered. This is Position #23851.

Applicants are invited to provide information regarding their gender, race and/or ethnicity, veteran's status and disability status on the form found at http://und.edu/affirmative-action/apcontrolcard.cfm. This information will remain confidential and separate from your application.

GEM
GLOBAL EARTHQUAKE MODEL
working together to assess risk

Global Earthquake Model (GEM) Secretary-General

The GEM Foundation invites applications for the position of Secretary-General, its organisational leader and chief executive. The role of Secretary-General has a predominantly external focus, with the responsibility to grow the organisation's leadership in collaborative assessment and reduction of earthquake risk. The successful candidate will demonstrate an extensive track record of success leading organisations or international initiatives in the domain of science policy or risk reduction. Responsibilities include strategy development and implementation, coordination of operational management, increasing the engagement of a wide range of public and private partners as well as development of institutional-level partnerships. The ideal candidate will have a PhD (or equivalent) in geophysics, engineering, political science, economics, or a related field, and a minimum of fifteen years' experience in organisational leadership with increasing levels of authority. We are seeking an individual with excellent communication skills, a demonstrated track record of diplomatic consensus-building among diverse stakeholders, and familiarity with disaster risk assessment or reduction programmes. The position is full-time and based in Pavia, Italy.

Please apply by **April 15th 2015** with a cover letter/email, your CV, at least 4 references and timeline of availability. Send applications to Claudio Boettcher, Vice-Chair of GEM's Governing Board: jobs_sg@globalquakemodel.org. Download the full job description at http://www.globalquakemodel.org/gem/organisation/jobs/.

UNIVERSITY OF CAMBRIDGE

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The Professorship of Mineralogy and Petrology

Department of Earth Sciences

The Board of Electors to the Professorship of Professor of Mineralogy and Petrology invite applications for this Professorship from persons whose work is connected with Solid Earth Sciences to take up an appointment in October 2015 or as soon as possible thereafter.

Candidates will have an outstanding research record of international stature in the Solid Earth Sciences, especially within the broad areas covered by petrology/geochemistry/mineralogy. The person appointed will provide leadership to the Department's multi-disciplinary research crossing petrology, geochemistry and mineralogy and have the vision, experience and enthusiasm to build on the Department's current strengths in order to maintain and develop our leading research presence. They will hold a PhD or equivalent postgraduate qualification.

Standard professorial duties include teaching and research, examining, supervision and administration. The Professor will be based at the Downing Site in central Cambridge. A competitive salary will be offered.

Further information is available at: www.admin.cam.ac.uk/offices/academic/secretary/professorships/ or contact the Academic Secretary, University Offices, The Old Schools, Cambridge, CB2 1TT, (email: ibise@admin.cam.ac.uk).

Applications, consisting of a letter of application, a statement of current and future research plans, a curriculum vitae and a publications list, along with details of three referees should be made online no later than 6 May 2015.

Informal enquiries may be made to Professor Jackson, Head of the Department of Earth Sciences, Cambridge, telephone +44 (0)1223 333481 or email jaj2@cam.ac.uk

The University values diversity and is committed to equality of opportunity.

ETH zürich

Professor of Climate and Weather Risks

→ The Department of Environmental Systems Science (www.usys.ethz.ch) at ETH Zurich invites applications for the above-mentioned professorship.

→ The position will be jointly at the Swiss Federal Office of Meteorology and Climatology (MeteoSwiss) and the Department of Environmental Systems Science. This framework provides a wide range of opportunities for collaboration in the areas of climate variability and uncertainty, as well as climate impact scenarios, Earth system science, the interpretation of climate model data, engineering and societal risks and others.

→ The successful candidate is expected to develop an innovative research program that makes important scientific contributions to methodologies managing climate and weather risks associated with both climate variability and climate change. The research portfolio should include quantitative methodologies using probabilistic approaches to address climate and weather risks, and include stakeholder involvement. The core research activity could be in one or more fields related to climate change adaptation, treatment of uncertainties in risk assessment, or linking climate and weather predictions and climate change scenarios to decision making. Candidates should have an excellent international track record in disciplinary as well as system-oriented multidisciplinary research, and be able to effectively lead a research team. Furthermore, the new professor is expected to develop classes for students focusing on the development of quantitative methods, and interdisciplinary courses introducing students to the challenges and successful practices in applied policy areas. Undergraduate level courses are taught in German or English, and graduate level courses in English.

→ **Please apply online at www.facultyaffairs.ethz.ch**

→ Applications should include a curriculum vitae, a list of publications, and a statement of future research and teaching interests. The letter of application should be addressed **to the President of ETH Zurich, Prof. Dr. Lino Guzzella. The closing date for applications is 15 May 2015.** ETH Zurich is an equal opportunity and family friendly employer and is further responsive to the needs of dual career couples. We specifically encourage women to apply.

The University of North Dakota is an Affirmative Action/Equal Opportunity Employer. The University of North Dakota encourages applications from women, minorities, veterans, and individuals with disabilities.

The University of North Dakota determines employment eligibility through the E-Verify System.

North Dakota veterans' preference does not apply to this position.

The University of North Dakota complies with the Jeanne Clery Disclosure of Campus Security Policy & Campus Crime Statistics Act. Information about UND campus security and crime statistics can be found at http://und.edu/discover/_files/docs/annual-security-report.pdf.

Ocean Sciences

PHYSICAL OCEANOGRAPHER/ MARINE GEOPHYSICIST Experimental Ocean Electrodynamics

The University of Washington Applied Physics Laboratory (APL) seeks a sea-going experimental physical oceanographer or marine geophysicist to lead a program in ocean electrodynamics. The successful candidate will be expected to develop an observational/experimental ocean or coastal research program with an emphasis on innovative sensor development and use. Present activities include theory, modeling, instrumentation, and field programs spanning basic research to applied and classified efforts. Historically, this program has implemented motionally induced voltage sensors on many platforms (e.g., ships, profilers, gliders, floats, drifters, landers and submarine cables) to study oceanic flows and turbulence. Newer topics include adding turbulence sensors to EM-APEX floats, EM remote salinity profiling in marine estuaries, observing the global electric circuit and installing EM sensors on NSF's OOI submarine cable. Several measurement systems are available for immediate use for both ocean velocity and magnetotelluric studies.

Candidates should have a demonstrated record of research and development in the ocean. A senior candidate should have existing funded projects. A junior candidate should have strong potential to fund independent projects. APL will provide bridge salary and support for engineering services. Candidates who can obtain a US security clearance are preferred. The Seattle area has an active oceanographic community with a variety of strong institutions and active colleagues.

For more information and to apply for this position, visit: http://www.apl.washington.edu/jobs/jobs.php

Solid Earth Geophysics

VISITING ASSISTANT PROFESSOR

Bucknell University's Department of Geology and Environmental Geosciences in Lewisburg, PA, seeks to hire a visiting assistant professor to teach two introductory lecture sec-

FACULTY POSITION – CLIMATE DYNAMICS

Young and research intensive, Nanyang Technological University (NTU), Singapore, is ranked 41st in the world and also placed 2nd globally among young elite universities. Its Earth Observatory of Singapore (EOS) and Division of Earth Sciences invite applications for an early- to mid-career Professor in climate dynamics.

We seek candidates holding Ph.D. degrees in Climate Science or closely related fields with exceptional and demonstrated accomplishment and promise in research and teaching, and with a strong interest in working with other EOS and SE Asian researchers on tropical climate dynamics and its teleconnections. Specific research interests may include but are not limited to understanding natural climate variability and anthropogenic climate change, coupling between oceans and atmosphere on various timescales, atmosphere-land-biosphere interactions, and combining numerical models and observational data.

Responsibilities include teaching undergraduate and graduate courses and building an extraordinary research programme. The successful candidate will play an important role in the expansion of the Division of Earth Sciences and the Earth Observatory of Singapore.

To apply, please submit the following materials to:
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- Cover Letter
- Curriculum vitae (To include list of publications and manuscripts in press)
- Statements of research and teaching interests
- A copy of three relevant publications
- Names of 3 references who are familiar with your work and willing to write an evaluation if requested by our search committee

Further information about EOS and the Division of Earth Sciences is available at www.earthobservatory.sg

Review of applications is on-going and will continue until the position is filled.

NANYANG TECHNOLOGICAL UNIVERSITY

EARTH OBSERVATORY OF SINGAPORE

tions of physical & environmental geology with two accompanying lab sections in the 2015 Fall semester. For full details and/or to apply on line, please visit http://apply.interfolio.com/28829. Review of applications will begin April 6, 2015. A position description can also be viewed on the Bucknell Department of Geology and Environmental Geosciences website at http://www.bucknell.edu/Geology. Bucknell University, an EEO Employer, believes that students learn best in a diverse, inclusive community and is therefore committed to academic excellence through diversity in its faculty, staff, and students. We seek candidates who are committed to Bucknell's efforts to create a climate that fosters the growth and development of a diverse student body, and we welcome applications from members of groups that have been historically underrepresented in higher education.

Interdisciplinary/Other

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Applications are invited for a full-time 8-month term position as Instructor in the Department of Earth Sciences at the University of New Brunswick to commence September 1 2015. We seek a candidate with expertise in structural geology to teach courses at the second, third and fourth year levels. Evidence of or demonstrated potential for excellence in teaching is required.

The successful candidate must have a minimum of an MSc and preferably hold a PhD in earth sciences or geological engineering.

Review of applications will begin immediately and continue until a suitable candidate is found.

This position is subject to final budgetary approval.

A letter of application including CV, statement of teaching interests and philosophy and the names of three referees should be sent to:

Dr Cliff Shaw, Chair
Department of Earth Sciences
University of New Brunswick
2 Bailey Drive
Fredericton, NB
E3B 5A3
cshaw@unb.ca

All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority. Applicants should indicate current citizenship status.

THE UNIVERSITY OF NEW BRUNSWICK IS COMMITTED TO THE PRINCIPLE OF EMPLOYMENT EQUITY

02/19/14

NASA seeks a new Director for the NASA Astrobiology Institute (NAI).

The ideal candidate will be an internationally recognized scientist with proven experience in leading or managing large interdisciplinary research programs or projects, possessed with a vision for leading the Institute into the future. Applicants for this position should have a broad scientific perspective on astrobiology, experience in conducting interdisciplinary scientific research, and demonstrated skills needed to harness the strengths of disparate research communities towards a greater goal. S/he should understand how to grow a research endeavor and respond to changing budget climates while focusing on maximizing the scientific return on NASA's investments in astrobiology. S/he should have experience in leading a diverse staff ranging from established scientists to support personnel, resource planning, and executing budgets and schedules. S/he should be comfortable with modern information technologies and distributed research teams. NASA is particularly interested in applicants who will find ways to infuse astrobiology into NASA flight missions.

The NAI Director is both the senior scientific officer and chief operating officer of the NAI. The Director coordinates scientific activities of the Institute's member teams and is responsible and held accountable for all operational aspects of the NAI, including the administration of personnel, budget and NASA policies. The Director will lead the NAI in fulfilling its mission to perform, support, and catalyze collaborative interdisciplinary astrobiology research; train the next generation of astrobiologists; provide scientific and technical leadership for astrobiology space mission investigations; develop new information technology approaches for collaborations among widely distributed investigators; and support K-12 education and public outreach programs.

Established in 1998 as part of NASA's Astrobiology Program, the NAI is a virtual, distributed organization of competitively-selected teams that conduct and integrate astrobiology research and training programs in concert with the national and international science communities. The Institute has 12 teams including ~600 researchers distributed across ~100 organizations as well as 13 international partner organizations. Headquartered at NASA Ames Research Center in the heart of California's Silicon Valley, the NAI links researchers across the US and around the globe using modern information technologies.

The NAI serves a vital role in advancing the goals of the larger NASA Astrobiology Program, with a focus on seeking the answers to these fundamental questions: How does life begin and evolve? Is there life beyond Earth and, if so, how can we detect it? What is the future of life on Earth and beyond?

U.S. citizenship is required for the NAI Director.

Interested individuals should apply directly to USAJobs at www.usajobs.gov. In the keyword search box, type vacancy number "AR15S0001". Select "Director, NASA Astrobiology Institute", then click "Apply Online".

NASA Ames Research Center does not discriminate in employment on the basis of race, color, religion, sex, national origin, political affiliation, sexual orientation, gender identity, marital status, disability and genetic information, age, membership in an employee organization, or other non-merit factor.

Thermochronology or Cosmogenic Isotopes Research Scientist and Lecturer Position, Univ. Tübingen, Germany

The Earth System Dynamics research group at the University of Tübingen, Germany, announces an open position (Assistant) in thermochronology or cosmogenic isotope analytical techniques. The preferred candidate will have demonstrated experience in running a thermochronology ((U-Th)/He, fission track) or cosmogenic isotope laboratory with application to problems in tectonics and surface processes. The candidate is expected to play a leading role in managing the research group and laboratories. Mentoring of students, proposal writing, collaborative research within the group, and teaching (in English and eventually German) a minimum of 4 hours per week are required. Position requirements include: (1) a PhD at the time of appointment, (2) experience in laboratory management, and (3) a collegial personality within a workgroup environment.

Salary is commensurate with experience (A13, 100%). The position is available for 3 years with a possibility for an additional 3-year appointment. The position also has the possibility to become permanent after an initial evaluation period. Interested persons should send a CV with a list of peer review publications, 1 page statement of research interests, past laboratory management experience, and contact information for three references. Application materials (in a single PDF file) and questions concerning this position should be directed to Todd Ehlers at todd.ehlers@uni-tuebingen.de. Applications should be submitted by May 1, 2015. The start date for the position is negotiable, but preferably in the fall of 2015.

The University of T¸bingen is committed to increasing the proportion of women in research and teaching positions and therefore encourages qualified candidates to apply. Disabled persons will be given preference if equally qualified. Employment takes place via the Central Administration of the University.

Student Opportunities

M.Sc or Ph.D Student at Memorial University, St. John's, Canada

Graduate position in biogeochemical cycling of atmospheric and terrestrial reactive nitrogen at the Newfoundland and Labrador Boreal Ecosystem Latitudinal Transect (NL-BELT) is available. The project aims to understand exchange processes of gas and particulate at the atmosphere-biosphere interface. Analytical, biogeo, or atmospheric chemistry an asset. Inquire/apply to Dr. Trevor VandenBoer (tvandenboer@mun.ca) until June 1

FACULTY POSITION - PHYSICAL OCEANOGRAPHY

Young and research intensive, Nanyang Technological University (NTU), Singapore, is ranked 41st in the world and also placed 2nd globally among young elite universities. Its Earth Observatory of Singapore (EOS) and Division of Earth Sciences invite applications for an early- to mid-career Professor in physical oceanography.

We seek candidates holding Ph.D. degrees in Physical Oceanography or closely related fields with exceptional and demonstrated accomplishment and promise in research and teaching and with a strong interest in working with other EOS and Southeast Asian researchers. Specific research interests may include but are not limited to understanding tropical ocean dynamics, using historical observations to model ocean changes, and investigating interactions between ocean circulation, regional atmospheric/climatic processes and sea-level change.

Responsibilities include teaching undergraduate and graduate courses and building an extraordinary research program. The person holding this position will play an important role in the expansion of EOS and the Division of Earth Sciences.

To apply, please submit the following materials to:
eos_humanresources@ntu.edu.sg

- Cover letter
- Curriculum vitae (to include list of publications & manuscripts in press)
- Statement of research and teaching interests
- A copy of three relevant publications
- Names of 3 references who are familiar with your work and willing to write an evaluation if requested by our search committee

Further information about EOS and the Division of Earth Sciences is available at **www.earthobservatory.sg**

Review of applications is on-going and will continue until the position is filled.

NANYANG TECHNOLOGICAL UNIVERSITY

EARTH OBSERVATORY OF SINGAPORE

Postcards from the Field

Dear Everyone,

There are few active volcanoes in the world as accessible as the Mt. Yasur cinder cone in Tanna, Vanuatu. With only a local guide, you can walk right up to the caldera rim (if you dare), where eruptions occur every 2–3 minutes. I was able to collect some very fresh lava samples to complement the oceanfloor samples that we collected during the SO-229 cruise along the New Hebrides Arc-Backarc.

Wish you were here,
Melissa Anderson
Ph.D. student at the University of Ottawa, Canada

View more postcards at *http://americangeophysicalunion.tumblr.com/tagged/postcards-from-the-field.*